ANNUAL REPORT

1960

Southeastern Forest Experiment Station
Asheville, North Carolina
Joseph. F. Pechanec, Director
ervice - U.S. Department of Agriculture

FOREWORD

Highlights of research accomplishment in 1960, when compared to those of 1946 or 1950, show dramatic evidence of progress. It is clear we know more about producing, protecting, and using resources from forest lands than we did ten or fifteen years ago. It is also clear that the emphasis in certain aspects of our program has changed.

New lines of investigation have been added, such as those related to wildlife habitat, forest recreation, and management and improvement of wetlands. We have changed from primary concern about natural regeneration to concern regarding artificial regeneration with improved strains on prepared seedbeds. We are delving deeper into the fundamentals, as illustrated by research on ignition and combustion, on the relation of mycorrhizal fungi to soil-borne pathogens, and on the physiological and biochemical processes involved in flowering and seed production of forest trees.

Not so clearly evident from a comparison of this and former reports is the change in type of researcher and facilities for his work. Though the Station is still an organization predominantly staffed by research foresters, we have of recent years been acquiring a major component of other needed specialists, such as plant physiologists, physicists, engineers, nematologists, hydrologists, chemists, and others. With the Southern Forest Fire Laboratory and the Seed Laboratory at Macon, provided cooperatively by the Georgia Forestry Commission and Research Council, the new laboratory-office building near Lake City, Florida, and the forest biology laboratory that is to be constructed in North Carolina's Research Triangle, we are beginning to get modern laboratories and equipment needed for more searching and efficient research.

The comparison also reveals that some major problems which loomed large ten or fifteen years ago are still with us. Though advances have been made, they are not the great strides we would wish. We're still concerned with effective and efficient control methods for low-value competitive shrubs, trees, and forbs in the forest — and the forest survey shows the extent of the problem is increasing. The emerging problems involved in protecting forests against insect and disease enemies exceed our capacity to provide methods for coping with them. We still have not the needed understanding of conditions conducive to blowup fires. These are only a few examples of serious gaps.

In general, progress has been good. But our development of knowledge is not rapid enough. We must learn how to move faster, even though ideas, imagination, and essential solutions do not lend themselves to production-line procedures.

Joseph F. Pechanec

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1960 Annual Report of the Southeastern Forest Experiment Station

FOREST ECONOMICS

The third Forest Survey of the southeastern states is now well under way (fig. 1). The South Carolina Survey has been completed (fig. 2), the final report winding up work in Florida is about to be published, and Georgia field work, which commenced in August 1959, is now two-thirds finished. Preliminary statistics have been released for two of the five survey units in Georgia, and the schedule calls for finishing field work in the State late this summer.

Forest Survey activities also included two special techniques studies. The first tried out a method for compiling all timber resource information by size of ownership, since the Timber Resource Review showed and subsequent surveys confirm that forestry accomplishments and problems vary greatly by type of ownership. Furthermore, ownership information helps to indicate how much of the timber is already committed and how much still available for new wood-using plants. The Survey has provided breakdowns by several classes of public and private ownerships for several years. A further breakdown by size of ownership would be useful. The recent trial proved that the double classification can be obtained, but only at a considerable increase over current expenditures for ownership data.

The second study, which will continue into 1961, is aimed at developing better equations for computing tree volumes. The Forest Survey abandoned the use of volume tables in favor of equations some two years ago. The equations now in use, although of the desired accuracy, are cumbersome to handle on the electronic data processing machines available to us. Indications are that equations of simpler form now being tested will overcome this objection without sacrifice of accuracy.

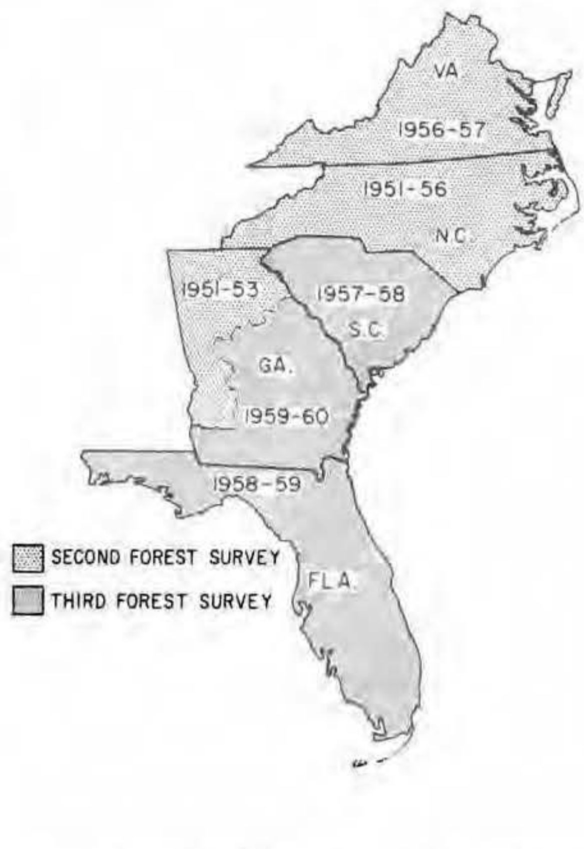


Figure 1.—Status of Forest Survey field work in the Southeastern States.

Figure 2.—Governor Ernest S. Hollings of South Carolina, second from left, receives the recently issued report, "South Carolina's Timber." Making the presentation are, left, C. H. Niederhof, West Virginia Pulp and Paper Co., Chairman of the legislative Forestry Study Committee; second from right, Thomas Lotti, Leader of Station's Charleston Research Center; and right, Charles H. Flory, State Forester, S. C. State Commission of Forestry. The report provides basic facts for a new South Carolina forestry program now being prepared.

Cooperation with the Southern Forest Experiment Station resulted in a publication containing distribution maps for 11 softwood species important in the South (fig. 3). This appeared as Forest Survey Release 83 of the Southern Station.

The Southeastern and Southern Stations also cooperated with the Southern Pulpwood Conservation Association on the regular annual survey of pulpwood production, this time for the year 1959. Production in the South set another all-time record — nearly 23 million cords. Altogether, 81 pulpmills drew wood from the South, of which 76 are southern mills. Production increase averaged 12 percent southwide. For the twelfth year, Georgia was the leading producer, with Alabama continuing as a strong second, and

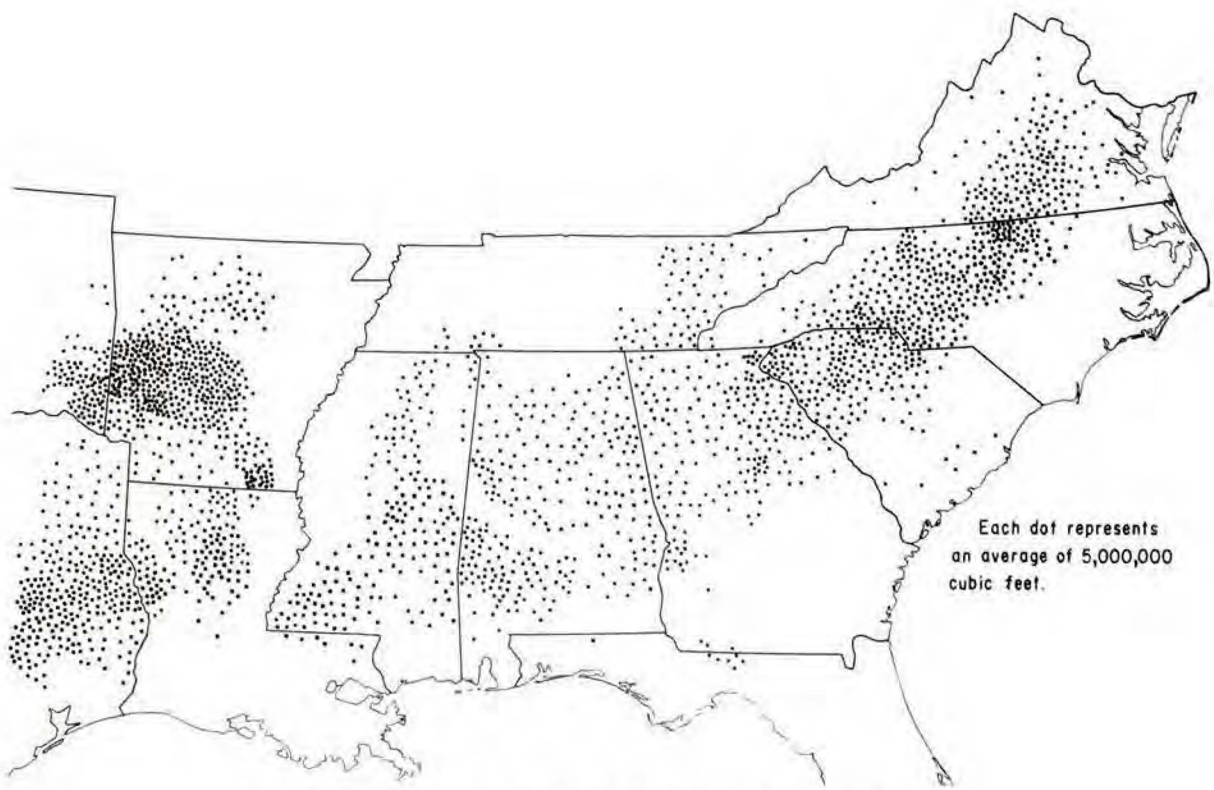


Figure 3.—Distribution of shortleaf pine (Pinus echinata) in the South.

North Carolina, South Carolina, Florida, and Mississippi practically tied for third place (table 1). Pine roundwood (bolts cut from standing timber) provides about four-fifths of the wood pulped (table 2), but it is losing ground as the mainstay of the industry; hardwood production was up a record 28 percent from the previous year, and use of residues rose 38 percent. The increased use of chips from sawmills has been phenomenal; starting from nothing in 1952, chip purchases now total nearly 2.4 million cords (fig. 4).

A companion study brought to date a pulpwood price series extending back to 1938.

Another publication was a guide to the identification of southern forest types on aerial photographs. The report shows important differences between paired panchromatic and infrared photographs made from simultaneous exposures by paired aerial cameras (fig. 5).

As usual, the Forest Survey staff has also devoted much time to answering requests for specialized types of information. The largest single order was from the U. S. Study Commission, Southeast River Basins. The Commission needed a large number of resource tabulations for each of eight major drainages.

Table 1.—1959 pulpwood production in the South and change from 1958

State	Round pulpwood and residues	Change
	Thousand cords	Percent
Alabama	2,931.0	+12
Arkansas	1,524.3	+16
Florida	2,113.4	+15
Georgia	4,735.1	+16
Louisiana	1,799.6	+14
Mississippi	2,015.8	+ 7
North Carolina	2,145.8	+13
Oklahoma	54.8	-13
South Carolina	1,933.3	+11
Tennessee	353.0	(1/)
Texas	1,415.6	+ 2
Virginia	1,728.4	+19
All states	22,750.1	+12

1/ Negligible.

Table 2.—Pulpwood production by type of wood, 1956-1959

Type of wood	Production			
	1956	1957	1958	1959
	- - Thousand cords - -			
Round pine	16,920	15,714	15,503	16,515
Round hardwood	2,766	2,866	2,944	3,773
Pine chips	488	1,047	1,581	2,177
Hardwood chips	46	78	146	207
Other pine residue	15	11	8	9
Other hardwood residue	110	67	51	69
All types	20,345	19,783	20,233	22,750

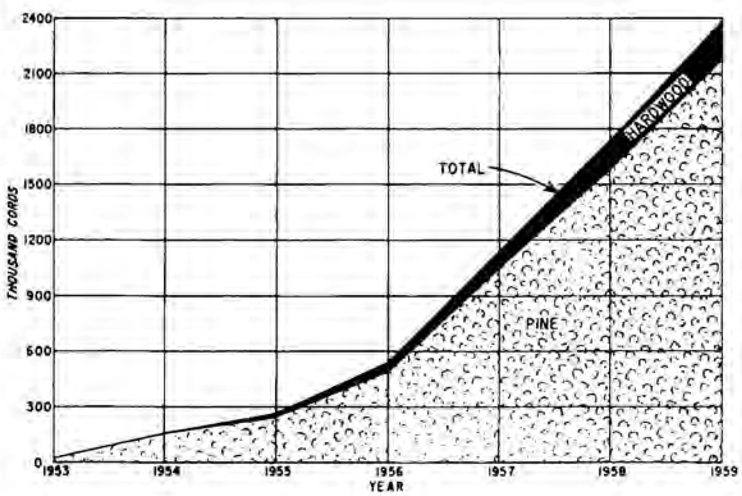


Figure 4.—Chipped-residue production, 1953-1959.

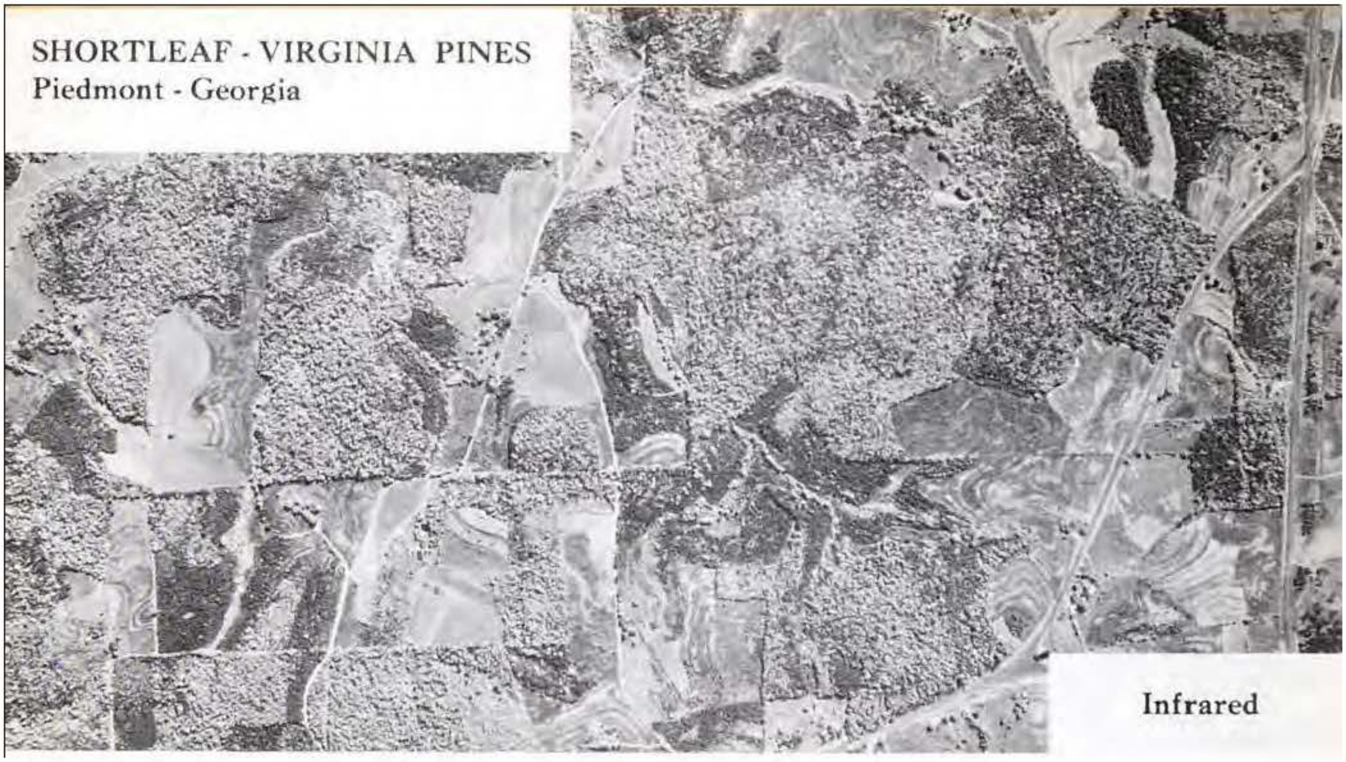
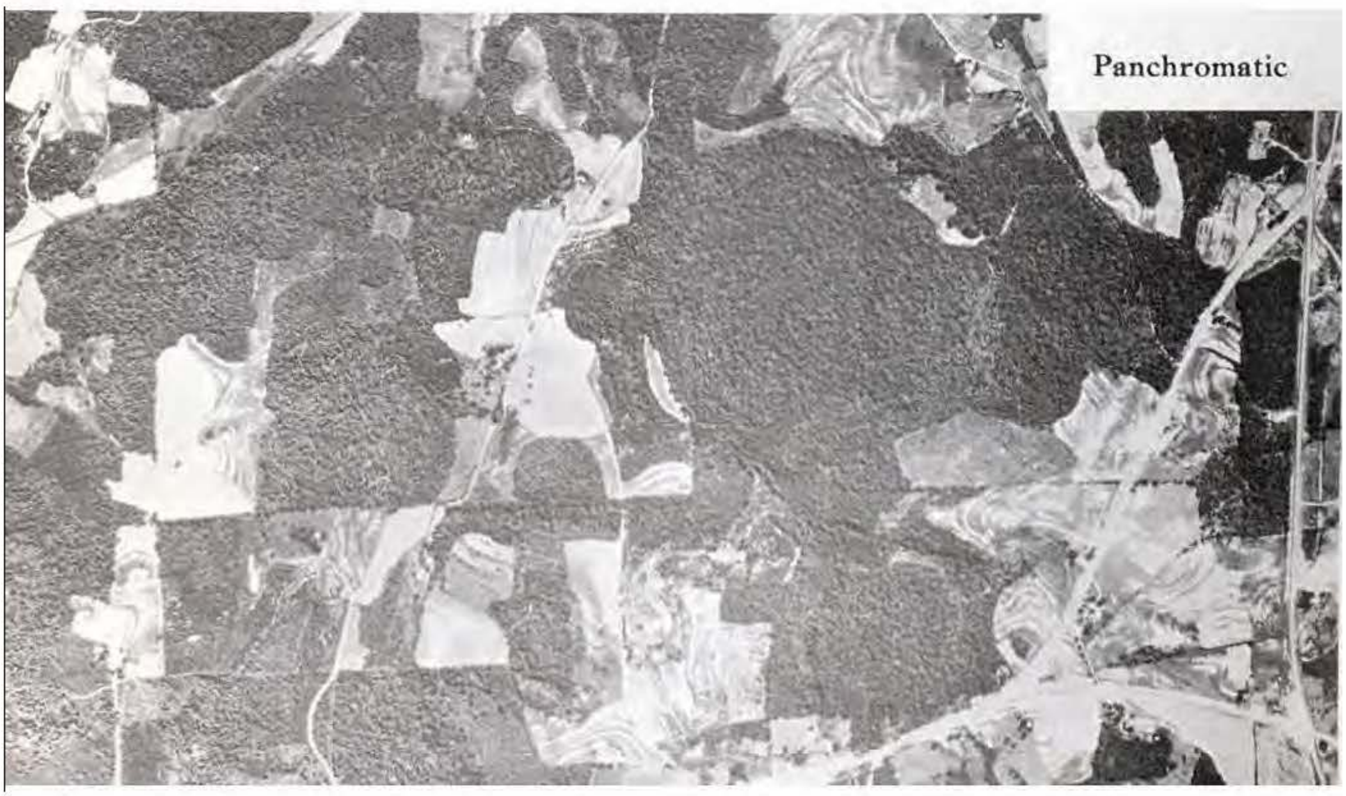


Figure 5.—A classical comparison of infrared and panchromatic aerial photography for timber type-mapping. Both pure and mixed pine-hardwood stands can be readily delineated on the infrared print (pine crowns are dark); types are much more difficult to distinguish on the even-toned panchromatic. However, note that lanes, field terraces, and boundaries appear clearer on panchromatic.



Florida Facts

Some highlights of the pending report on the Florida Survey are as follows:

Today, Florida has 11 percent less commercial forest land than in 1936 when the first survey was completed; the State contains about the same volume of pine timber, but nearly a third more volume in cypress and hardwood trees, mainly in small low-value trees. Volume in pine trees 15.0 inches and larger decreased 50 percent, but the volume in 6- and 8-inch pines increased 41 percent. Some 5½ million fewer acres are growing pine, but the area still qualifying as pine type is much better stocked now than in 1936. Florida now has twice as many pine trees 1.0 inch and larger. The increased number of pine trees is mainly a response to better fire protection. In 1936, only 3.5 million acres of Florida's forest was protected, compared to 17.3 million acres today. Hardwoods are increasing in number twice as fast as the pines and are taking over more and more of the former pine land. About half of Florida's forest land is poorly stocked and unlikely to restock itself with desirable timber (fig. 6). Aids to small owners (fig. 7) and the current stepped-up planting activity, however, promise to go a long way towards putting these idle acres to work. During the 1958-1959 season alone, nearly 200 million pine trees were planted. In 30 years, with adequate protection and conservative cutting, the growth of these plantations could be enough to replace the current cut of pine. Right now, Florida offers excellent opportunities for industries that can use low-value hardwoods and small cypress, since growth of this type timber is well in excess of the cut.

Figure 6.—Three out of five acres cut over annually in Florida require planting, usually preceded by site preparation, to insure prompt restocking.

Figure 7.—Help for Florida farmers and other small private owners is available both from the wood-using industries and from public agencies to make their land grow more and better timber.

New Survey of Southwest Georgia Completed

The third Forest Survey of Southwest Georgia was completed in January of 1960. Previous surveys were made in 1934 and 1951, but this most recent one is the first in which measurements were recorded at the same locations as in the preceding survey. The refinement made possible better estimation of changes due to timber cutting and mortality.

A comparison of results from these three surveys shows very little change in forest area over the past 26 years. Forests now occupy 3.1 million acres, or 54 percent of the total area in Southwest Georgia. However, while the forest area has remained about the same, less of it is now growing pine. Between 1934 and 1951, hardwoods have replaced pine on 417,600 acres, and since 1951 on 155,700 acres (fig. 8).

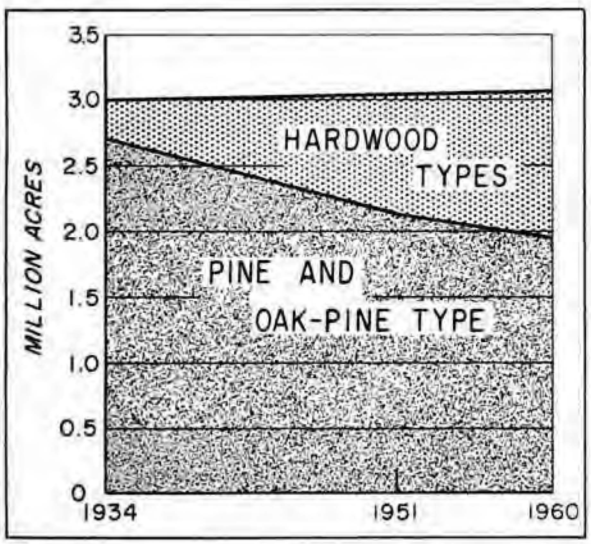


Figure 8.—Hardwood types have steadily gained at the expense of pine types over the past 26 years in Southwest Georgia.

The third survey shows a reversal of the upward trend in timber volume revealed by the 1951 survey. Since 1951, cutting and mortality in excess of growth have reduced the total volume of both softwoods and hardwoods (fig. 9). This growth deficit has averaged 11.0 million cubic feet per year for softwoods and 2.9 million for hardwoods. Between 1934 and 1951, the softwood volume increased 10 percent but has dropped 8 percent during the succeeding 9 years. Hardwood volume nearly doubled during the period between the first and second surveys but has decreased 5 percent since 1951.

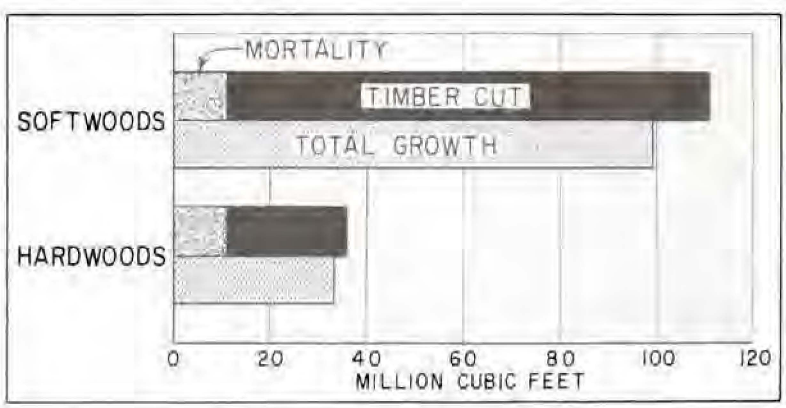
Because of the reduction in softwood volume, Southwest Georgia is growing 4 percent less softwood timber now than in 1951.

Even though hardwoods have replaced pine on a substantial area in this section of the State, the area still growing pine is better stocked than formerly. The establishment of many small trees in response to better fire protection and planting has increased the number of softwood trees 18 percent in the past 9 years. If cutting can be brought in line with growth, fire protection continued, and management improved, the increase in numbers of small trees should show up as an addition to growth during the next 10 years.

Preventing overcutting and increasing growth will be largely a matter of getting better management into farm woodlands, for farmers own 84 percent of the forest land in Southwest Georgia.

A good start was also made on a new farm forestry study, with substantial help from the Station's Division of Forest Management Research. This study, at Charlottesville, Virginia, is being conducted in cooperation with the Virginia Agricultural Experiment Station to determine how forestry can be combined with field crop and livestock enterprises to obtain maximum total income on farms in the southern Piedmont of Virginia. The project has sampled 105 typical farms, obtained information on costs and returns from forest management, and is attempting to find the optimum combination of enterprises for these typical farms.

Figure 9.—Annual growth of both softwoods and hardwoods has averaged less than cut and mortality over the past 9 years in southwest Georgia. Softwoods show a deficit of 11 million, and hardwoods 2.9 million cubic feet.



FOREST MANAGEMENT

Much of our research is designed to answer specific questions about specific phases of forest management. But at some stage it becomes necessary to build from these small tests larger studies which can more directly answer the problems of the forest manager. The emphasis of this section this year is on small woodland management, growth and yield, and large-scale, long-term compartment or pilot-plant studies that integrate our best knowledge into actual forest management practices.

Following World War II and at an increasing tempo since that time, some of the most pressing questions have dealt with management decisions. How do I manage a small woodlot, and what can I reasonably expect in financial returns? Under a given set of stand and site conditions, what growth and yield can I expect? How can I successfully regenerate my pine or hardwood stands and still get the highest annual return?

These questions have not all been answered in the last 15 years for the southeastern states, but we have obtained considerable information that may help forest managers. This report summarizes results recently published or soon to be available.

SMALL WOODLAND MANAGEMENT

Nearly 75 percent of the private forest land in the South has been classified as small ownerships. The problem of securing satisfactory management of forest lands in this category has been emphasized in recent years, but actually it is a problem of long standing in the region.

Two major projects of the Southeastern Station have been aimed specifically at the needs of the small owner in the management of his woodland. One of these efforts has been reported in the Economics section and deals with a study of farm forestry economics in Virginia. The other major project covers farm woodlot management studies.

The Station has 17 farm woodlots under study; results cover periods of from 5 to 15 years on 15 of these at seven locations (fig. 10). Some are in the mountains, some are in the Piedmont, and others are in the coastal plain. They cover a wide range of timber types, initial stand conditions, and timber markets. Some have been highly profitable; some have had comparatively low returns (fig. 11).

A 33-acre area on the Santee Experimental Forest near Charleston, South Carolina, studied for a 10-year period, demonstrates that an owner can make an annual profit while improving quality and increasing the value and production of his woodlot. Net returns from stumpage plus the value of increased growing stock averaged over $11 an acre a year.

In 1950, the trees were limby, overmature, and of a poor quality. Two cuts on the woodlot, spaced so that each portion of the tract received an improvement cut at 5-year intervals, yielded a harvest of 60,000 board feet of sawtimber and over 93 cords of pulpwood. In addition, the owner had 28 percent more sawtimber in his stand in 1960 than when he started (fig. 12).

A portion of the increased growth and better stocking is a direct result of releasing pines from overtopping, low-quality hardwoods. A small area (1.4 acres) was planted, and free-to-grow seedlings now occupy most of the space which was previously nonproductive.

Figure 10.—The farm woodlots under study are typical of the southeastern states and show a range in timber types and topography. Initial stocking was in general better than most farm woodlots in the region.

The mountain woodlots near Asheville, N. C., with 15 years of record, are predominantly hardwood stands. At Macon, Georgia, there is a clear-cut and plant farm woodlot (pictured here) as well as three woodlots that have received a selective cutting. The Cordele, Georgia, woodlot has had 9 seasons of record and the Lake City, Florida, woodlot 15 seasons. Both are managed for integrated use of timber and naval stores. Initial stocking on the Charleston, S. C., woodlot was 3,300 board feet (Doyle rule) and 3 cords of pulpwood per acre; average site index is 90 — about average for loblolly pine in that locality. Near Statesville, N. C., two woodlots were established in 1955 in mixed hardwood and pine stands with good initial stocking and on sites capable of growing high quality hardwoods. One of the woodlots at Franklin, Virginia, has provided a 5-year case history of reducing excessive growing stock.

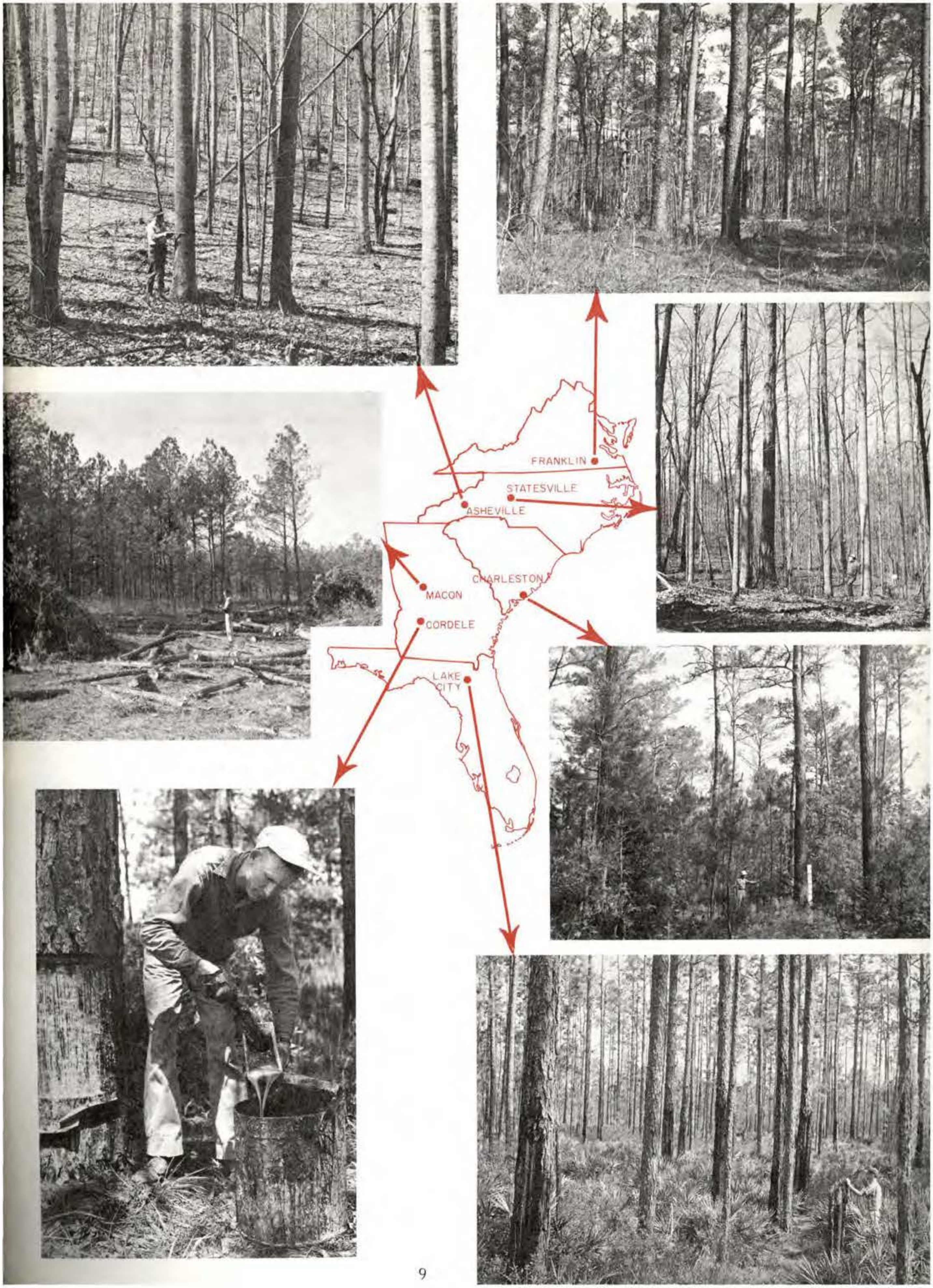

FRANKLIN
STATESVILLE
ASHEVILLE
CHARLESTON
MACON
CORDELE
LAKE CITY

Figure 11.—If these small woodlands are to be productive, a number of operations must be carried out. If low-grade trees occupy too much space, girdling or herbicides (A) will control undesirable hardwoods and provide openings for reproduction of desirable species.

In many areas fire protection, including pastured firebreaks, has been helpful in protecting the growing timber (B). Open areas need planting (C), and good marking practices help eliminate poor growing stock (D).

Some woodlot owners conduct their own harvesting operations (E, F, G). Others sell stumpage to a contractor who then fells the marked trees, bucks, skids, loads, and hauls the timber products to market. Still other small woodlot owners conduct only a part of the harvesting and sell the harvested products at roadside.


D


E


F


G

Had the owner elected to clearcut this tract in 1950 with no provision for regeneration — an all too frequent choice — he would have received \$2,925 for his timber. This money invested at 6 percent would have appreciated to \$5,329 in 1960. Stumpage rates in 1960 are much higher than in 1950, and the residual growing stock (wood on the ground) is worth \$8,139 today. Sale of stumpage less all management expenses has brought in \$894. But even when calculated at a constant stumpage rate, the return on the investment since 1950 is 6.4 percent, and the area is still only 70 percent stocked. Future growth should result in even better returns. Small woodlots producing hardwood products can also give good returns, as evidenced by a \$10.36 per acre per year return on one farm woodlot with high quality growing stock near Statesville, N. C.

Not all the farm woodlots have shown as encouraging a picture as the one on the Santee in terms of dollar return (fig. 13) or net growth (fig. 14). For example, a woodlot located on a poor site in the Southern Appalachians yielded only \$4.50 per acre per year over a 15-year period.

At the Hitchiti Experimental Forest near Macon, Georgia, one 40-acre management unit is operated on a pulpwood rotation. One acre is harvested each year and then planted. This method of management has provided the owner with a good opportunity to harvest each year the acre most in need of harvesting and keeps the area in full production. In addition to providing an annual income, this method of management has kept the value of the property at a high level for sale purposes.

On the woodlots at the George Walton Experimental Forest near Cordele, Georgia, and the Olustee Experimental Forest near Lake City, Florida, gum naval stores have been harvested in addition to sawtimber and pulpwood. Each acre has returned \$2.70 net each year from naval stores operations alone on the Cordele area; at current naval stores prices, the net profit from turpentining would be raised to \$8.95.

A woodlot study at Franklin, Virginia, has demonstrated a method of stand management which can be used to reduce growing stock systematically and at the same time promote regeneration in mature and overmature stands. By annually harvesting 500 board feet per acre per year, investing fifty cents per acre per year to aid regeneration in openings, and expending a total of \$2.75 per acre for cultural operations, this area has increased its growth rate of usable wood from 213 to 413 board feet per acre per year, has bettered the age-class balance in the holding, and provided a sizeable cash income to the owner over a sustained period of time.

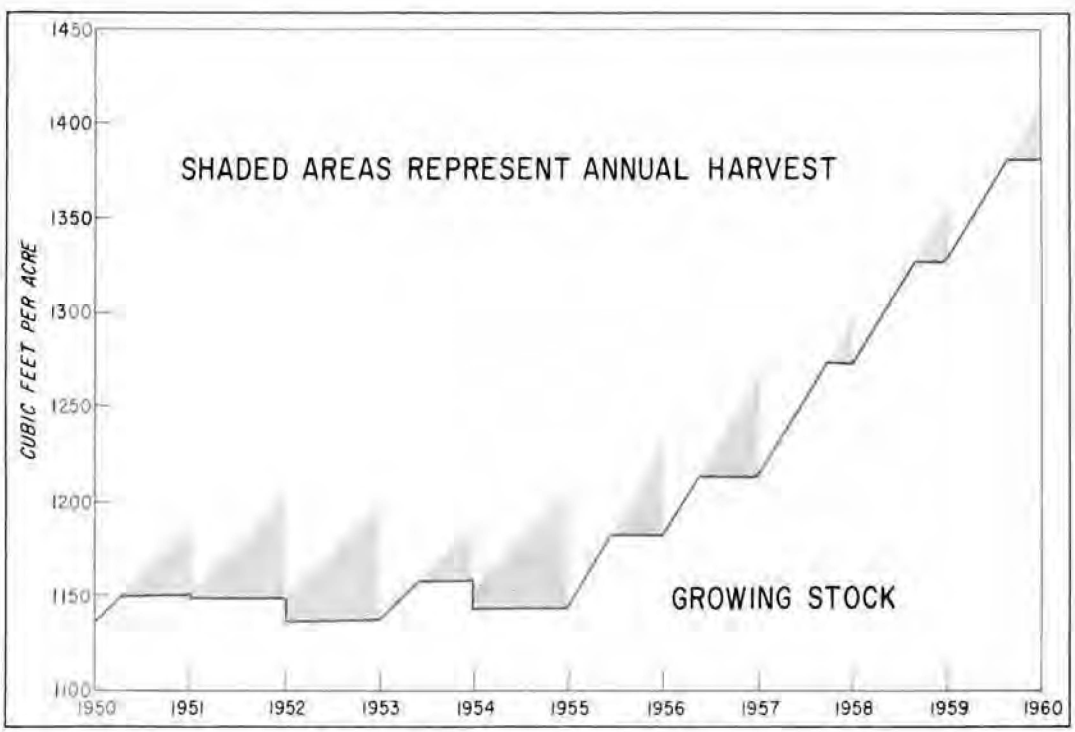


Figure 12.—Cubic-foot volume per acre, 1950 through 1960, at the Santee Experimental Forest near Charleston, South Carolina.

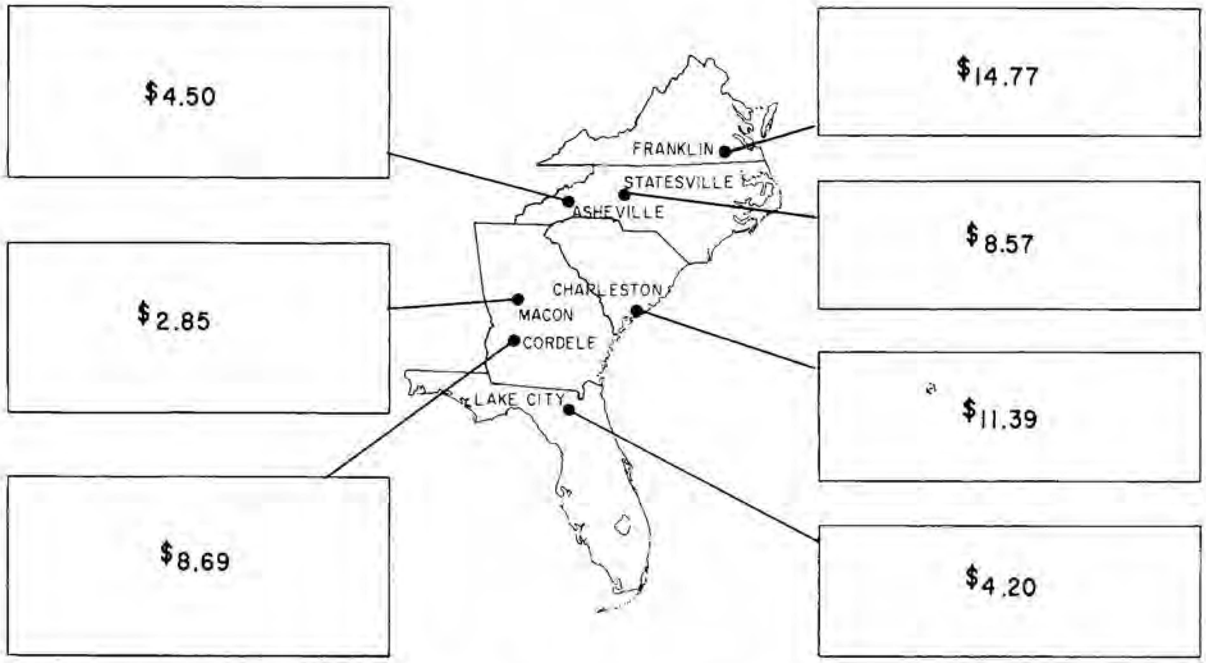


Figure 13.—These net returns per acre per year represent cash income plus the net increase in value of growing stock. The original condition of the stand was perhaps the greatest single contributing factor to the differences in net returns. Next in importance has been the increasing value of forest products; areas with similar stand conditions but a shorter period of record show higher average annual returns.

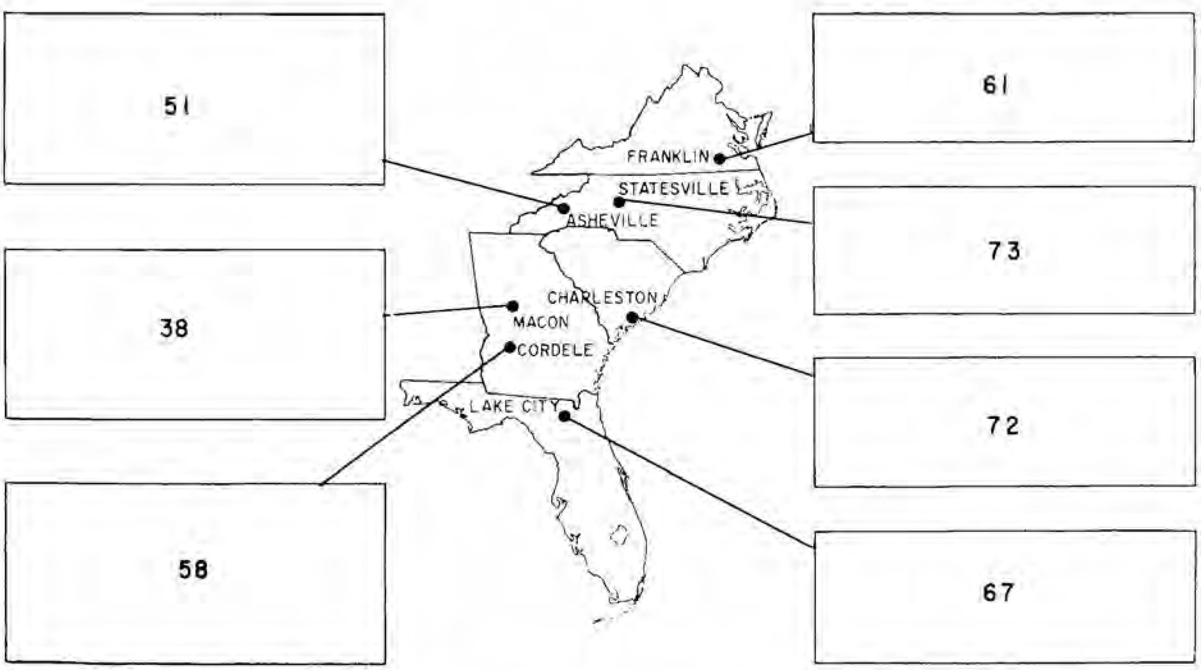


Figure 14.—Net growth in merchantable cubic feet per acre per year is surprisingly uniform for the various farm woodlot locations. Original condition—poor stocking—accounts for the low value on the Macon "clearcut and plant" farm woodlot.

YIELD AND GROWTH

To realize profits, the manager of any business enterprise must accurately estimate costs and returns from various phases of his operations. The forest manager has an added complication; his returns attributable to any given cost item accrue years or decades later.

Costs are usually obtained through experience; cost control systems — formal or informal — are an integral part of day-to-day operations. Returns, at least when expressed in some measure of the amount of wood produced, can also be obtained by experience. By keeping careful records, the forest manager can determine the amount of wood produced on a given tract of land over its rotation. Because most forestry operations have not been under way long enough to obtain yield or growth records, experiments have been established to predict the amount of wood produced as various products for a range of ages, sites, and stand densities.

Some of these studies measure plots which have not been managed, and the results predict the total yield which similar areas should produce. An example of such a study for slash pine plantations was published as Station Paper 107 by Bennett, McGee, and Clutter. During the past year studies were completed for predicting the cubic-foot yield of Virginia pine natural stands, south Florida slash pine natural stands, and eastern white pine plantations.

Other studies were installed simply to predict growth between short periods or cutting cycles in the stand rotation. In the last two years, growth analyses have been completed on a compartment study of old-field loblolly pine in the lower Piedmont of Georgia, a regional stand density study of loblolly pine, and a study in young slash pine stands. Other growth studies have been installed with different species or stand conditions.

YIELD STUDIES

Slash pine plantations in 43 counties of the Georgia middle coastal plain and 14 in the Carolina Sandhills were sampled for yield data (fig. 15). Volume tables were built, site index curves were constructed, and wood yields in cubic feet were established in relation to age, site index, and stand density. Approximately 86 percent of the variation in cubic-foot yield was explained using the model:

$$\text{Log of yield in cubic feet} = b_0 - b_1\left(\frac{1}{\text{age}}\right) - b_2(\text{site index}) - b_3\log\left(\frac{\text{square feet per acre}}{\text{survival (in percent)}}\right) - b_4\left(\frac{1}{\text{site index}}\right)$$

where b with subscripts equals constants.

As an adjunct to the slash pine yield study, equations were developed for predicting the height growth of slash pine plantations in the Sandhills of the Carolinas and the middle coastal plain of Georgia. In both areas, height at any age was highly correlated with thickness of the A_1 horizon and depth to fine-textured soil. An increasing thickness of the A_1 horizon is related to an increase in soil quality. In the Carolinas, increased depth to fine-textured soil has a detrimental effect on height growth. In Georgia, the relationship of fine-textured horizon depth to tree height growth is somewhat more involved. Optimum growth was found on sites having a depth to a fine-textured horizon of 28 to 30 inches. On sites where depth to a fine-textured horizon is greater than 30 inches, moisture becomes limiting because of the poor water-holding capacity of the surface horizons.

Virginia pine is the dominant species on many forest lands in Virginia and the Carolinas. Not many years ago it was classed as a forest weed, but in recent years the good pulping qualities of its wood, its heavy yields per acre, and its acceptance as sawtimber have led to an increasing interest in its productive capacity. Therefore, cubic-foot yield estimates have been computed for Virginia pine stands of various densities, growing on different sites, and with varying proportions of the forest stand in this species.

Because of the complicating factor of Virginia pine occurring with other species in many situations, the use of a composition correction factor (fig. 16) is necessary for yield prediction along with knowledge of age, density, and site index. The results of the study indicate that Virginia pine has the ability to produce higher cubic-foot yields than the aggregate of its competitors. For example, a stand composed of 40 percent Virginia pine will produce 51 percent of the yield of an equally stocked, pure Virginia pine stand of the same age on a comparable site.

In a south Florida slash pine study (fig. 17), over 90 percent of the variation in cubic-foot yield was found to be a function of age and interactions of age with site index and density. As expected, yields increased as stands became older, and were higher on good sites than on poor sites. Yields also increased as the stands became denser within the range of the stands sampled. The analyses also showed that mean annual growth generally culminates later on poorer sites and for any one given site later in the lower stand densities. An abbreviated yield table is presented in table 3.

Data were analyzed from 112 sample plots in eastern white pine plantations located in the mountains of western North Carolina and eastern Tennessee. Nearly 90 percent of the variation in yield of these plots was related to age, site index, and the original spacing of the plantations.

An advantage of using original spacing in predicting plantation yields is that it does not require

Table 3.—Condensed merchantable[1] cubic-foot volume yield table for slash pine stands in south Florida

Site index (Age 25)	Stand density index	Age (years) 20	30	40	50	60
		Cubic feet per acre (O. B.)				
30	100	360	880	1,350	1,760	2,100
	150	440	990	1,490	1,900	2,230
	200	530	1,120	1,640	2,050	2,380
	250	640	1,280	1,800	2,210	2,540
	300	780	1,450	1,980	2,390	2,710
50	100	880	1,580	2,110	2,510	2,820
	150	1,070	1,800	2,320	2,710	3,010
	200	1,300	2,040	2,560	2,930	3,210
	250	1,580	2,320	2,820	3,160	3,420
	300	1,910	2,640	3,100	3,420	3,650
70	100	2,160	2,870	3,300	3,590	3,800
	150	2,620	3,260	3,640	3,880	4,050
	200	3,180	3,700	4,000	4,190	4,320
	250	3,850	4,210	4,400	4,520	4,610
	300	4,660	4,790	4,850	4,890	4,910

1/ Includes merchantable cubic-foot volume of all trees 4.5 inches d.b.h. and larger to a top diameter of 3.5 inches inside bark.

an estimate of plantation survival sometime in the future. Such estimates are hard to make. Early survival of eastern white pine is probably a function of vegetative competition, weather conditions during the year following planting, care with which the planting is done, and condition of planting stock. Later on, spacing and site quality have an effect.

GROWTH STUDIES

Hitchiti Compartment Study

A compartment study was set up in 1945 on the Hitchiti Experimental Forest near Macon, Georgia, in old-field loblolly pine (fig. 18). At that time, 1,552 acres were divided into 202 stands. Net growth based on 100 percent plot inventories of merchantable stems at 5- to 12-year intervals provided growth data. Using multiple regression techniques, 68 percent of the variation in cubic-foot growth was accounted for by the expression:

$$\text{Cubic-foot growth} = -20.748 + 6.454(\text{basal area}) - 0.025(\text{basal area})^2 + 5.026\left(\frac{10{,}000}{\text{age} \times \text{site index}}\right) - 235.034\left(\frac{\text{basal area}}{\text{site index}}\right)$$

A board-foot growth analysis of the same stands showed that on average sites with moderate stocking the landowner can expect an average annual growth of 323 board feet, International ¼-inch rule. With some degree of management this growth can be increased to 450 board feet, and on good sites 600 board feet per acre per year can be expected. On average and above-average sites, board-foot growth cannot be increased an appreciable amount by increasing the stocking above 80 square feet basal area per acre.

Stand Density Studies

During 1949-1950, a regional stand density study in loblolly pine natural stands was established over a wide variety of sites, ages, and stand densities in Georgia, Virginia, and South Carolina. An analysis has recently been completed on the growth of these plots during the last 5-year period. In the thinned plots, over 78 percent of the variation in annual cubic-foot growth was explained by the expression:

$$\text{Cubic-foot growth} = 148.854 + 0.286\left(\frac{10{,}000}{\text{age}}\right) + 0.036(\text{basal area} \times \text{site}) - 0.012(\text{basal area})^2 - 6.796(\text{site}) + 0.045(\text{site})^2$$

The results are shown graphically in figure 19 for 50 years of age. Other measures of stocking in lieu of basal area have given essentially the same goodness of fit.

The stand density study approach provides a means of answering the question of how much growing stock to reserve during intermediate stand ages. The usual approach to the solution of this problem has been through thinning studies. Although the experience of practicing foresters is rich in isolated examples of the immediate bene-

Age (years)	Original spacing	Site index (age 25)			
		40	50	60	70
	Feet	Cubic feet per acre			
10	6 x 6	61	240	511	788
	6 x 7	57	225	478	738
	6 x 8	54	212	451	697
	8 x 8	48	188	400	617
	8 x 10	44	171	365	562
	10 x 10	40	156	333	514
	15 x 15	29	115	244	377
20	6 x 6	463	1812	3858	5952
	6 x 7	434	1697	3612	5571
	6 x 8	410	1603	3412	5230
	8 x 8	363	1419	3022	4595
	8 x 10	331	1295	2757	4190
	10 x 10	302	1183	2519	3800
	15 x 15	222	871	1834	2790

Figure 15.—Slash pine plantation yield study showing wide-spaced, thrifty **plantations. Inset is abbreviated yield table showing yields (outside bark). Plots were measured throughout ranges of 4 x 2 feet to 20 x 20 feet spacing, 10 to 28 years in age, and site indices (age 25) of 30 to 80.**

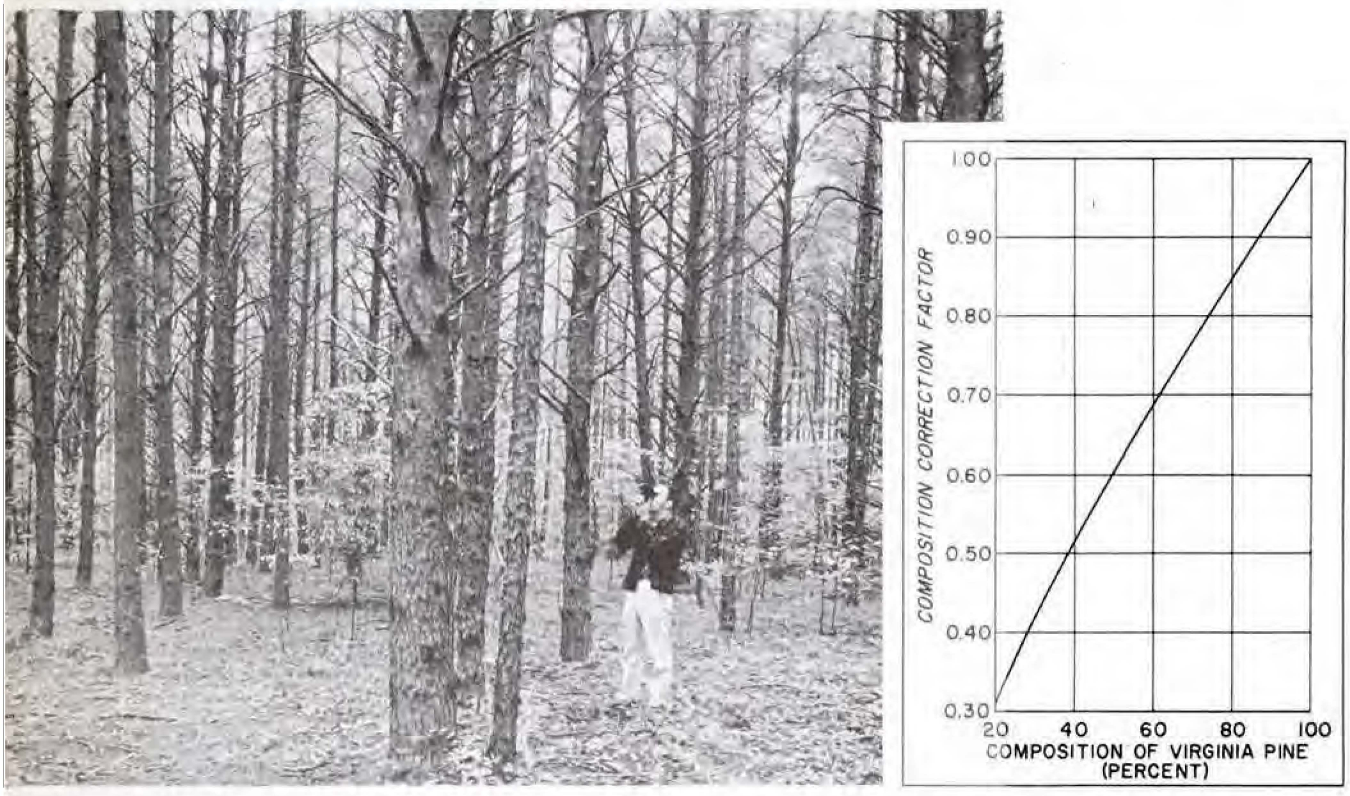
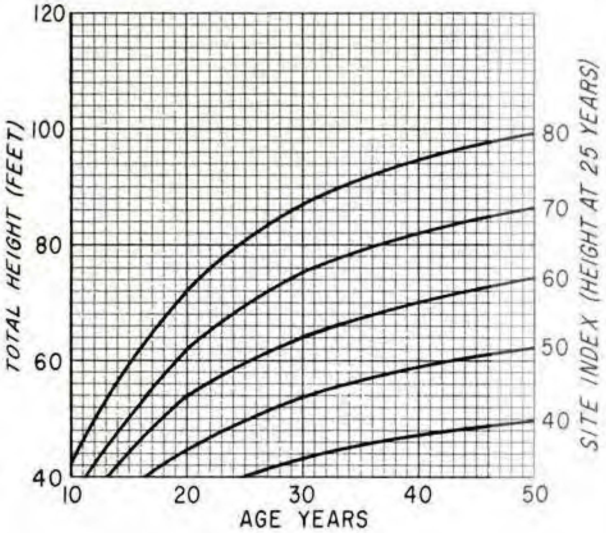


Figure 16.—Virginia pine yield study. A 34-year-old stand of Virginia pine in the North Carolina Piedmont with a basal area of 125 square feet per acre. Inset shows the method used in this study to correct yields for varying composition of Virginia pine in mixed species stands. Plots in this study were distributed throughout stands from age 10 to 60 and site classes from 50 to 80.



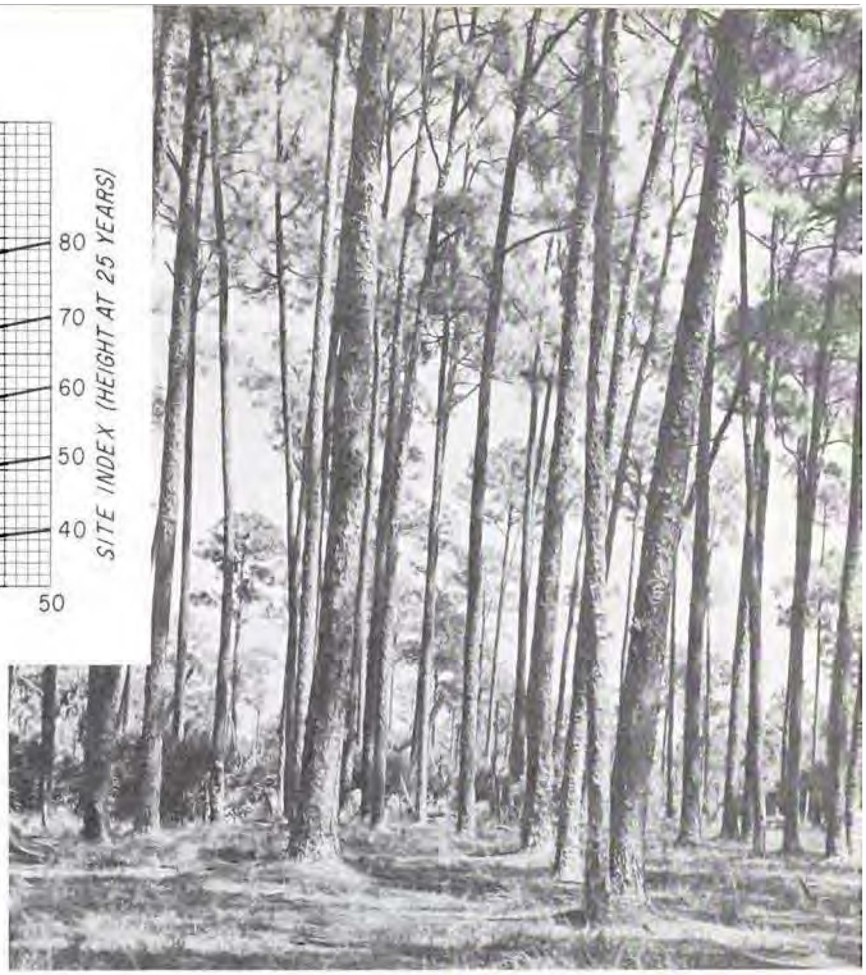


Figure 17.—Yield of slash pine stands in south Florida. This stand is better stocked than most forest lands in this area. Inset shows new site index curves for South Florida slash pine. This study included stands varying in age from 8 to 61 years, in site index (based on age 25) from 30 to 77, and in stand density index from 26 to 231.

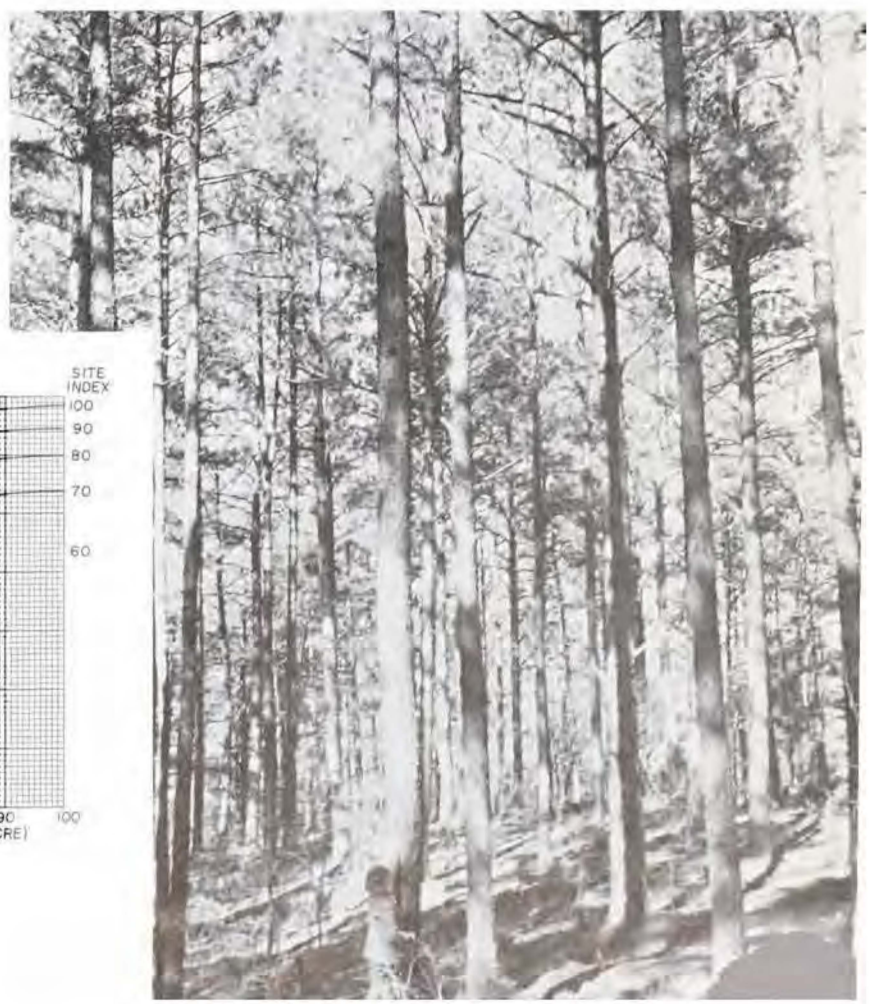
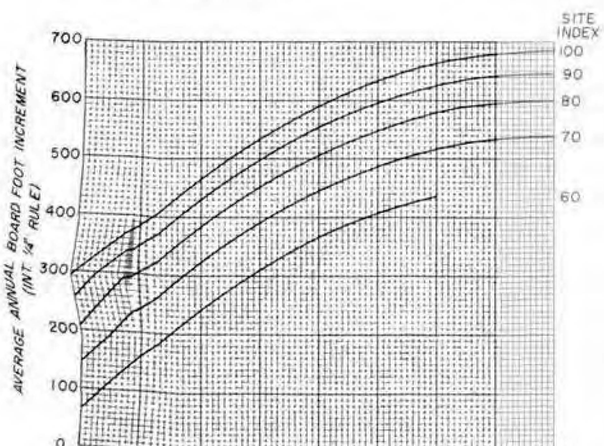


Figure 18.—Loblolly pine growth study. Piedmont stand of loblolly pine with near-average stocking. Inset has curves with average annual board-foot growth in relation to basal area stocking of trees 5.6 inches d.b.h. and larger.



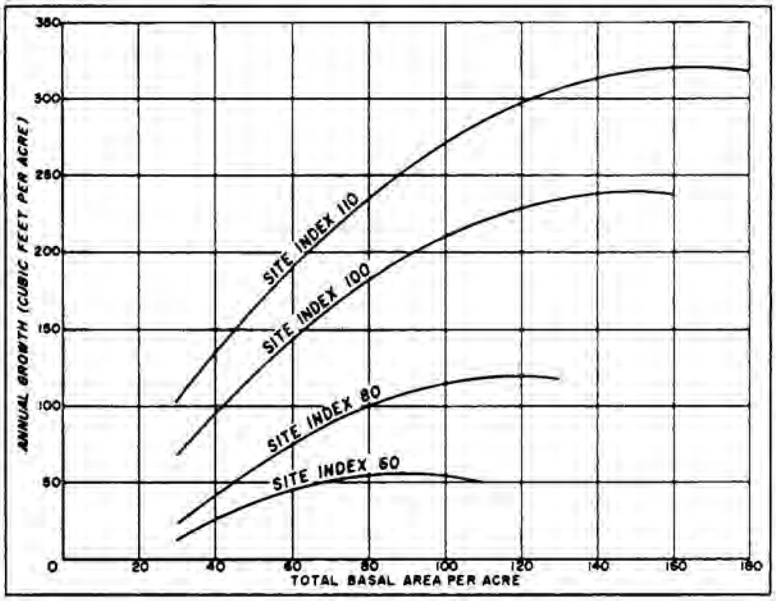


Figure 19.—Loblolly pine stand density study. Annual cubic-foot increment by site classes and stocking at age 50 where basal area is expressed as the total basal areas of all pine stems.

fits of thinning, there is little or no evidence of the logical extension of these studies to continuously controlled growing space and production curves. The basic assumption cultivated in this study is that an optimum growing space may exist for any combination of the biological factors of site and age. The basic design involved in this concept has been used in six stand density studies now on the ground or being installed in even-aged stands in pure types.

Young Slash Pine Study

A series of slash pine plots in stands ranging from 9 to 25 years of age and located in the flatwoods of Florida and Georgia provided data for regression analysis of their growth in relation to age, site, and stand density. The final equation which accounted for 89 percent of the variation in cubic-foot growth was:

$$\text{Periodic annual growth} = 0.589(\text{site}) - 0.033(\text{stand density})^2 + 0.051(\text{stand density} \times \text{site index}) + 0.0003[\text{age} \times (\text{stand density})^2] - 3.085$$

This study and the independently conducted stand density and compartment loblolly pine studies show an amazing degree of uniformity. The analyses all show age, site, and stand density to contribute significantly to growth relationships. In addition, the interrelationship of site index and stand density are significant in all three equations, indicating that maximum growth occurs at a higher stand density on good sites than on poor sites (fig. 20). All three studies produced relatively flat curve forms and showed that a wide range of stocking can be maintained within the forest stand, which is still capable of producing 90 percent of maximum growth.

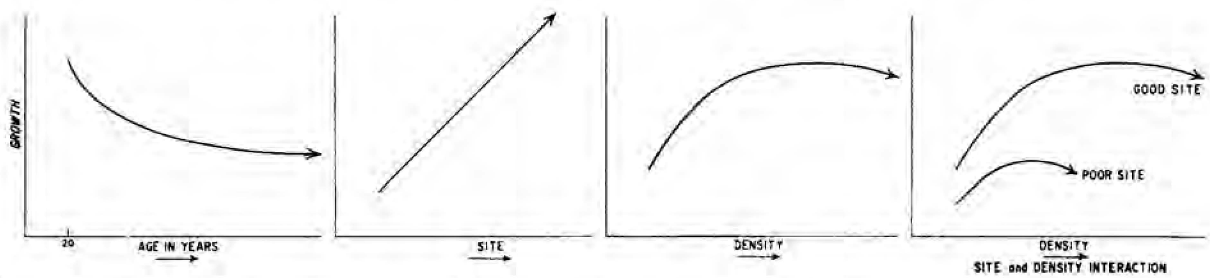


Figure 20.—Simplified diagrammatic sketch of the cubic-foot growth relationships to age, site, and stand density in loblolly pine stand density study, Hitchiti compartment study, and young slash pine study. Stands 20 years in age and older decreased in growth with age (A). Growth was greater on good sites than poor ones (B). Growth on a given site culminated before maximum stand densities were reached (C), and culminated at a lower density on poor sites than on good sites (D).

LARGE-SCALE TESTS

A logical progression from basic research to a wide-scale application of results usually involves several levels of studies. Laboratory results are tested in small plot studies; small plot study findings are then applied to larger areas for further testing under a greater range of forest conditions. Finally, a pilot-plant test involving best known management procedures precedes recommendations which may involve forest types or conditions covering hundreds of thousands or millions of acres. Two large-scale studies reached a stage during the past year where interim results of a substantial nature were obtained.

Hitchiti Compartment Study

Twelve years of study with large-scale tests of managing loblolly pine on the Hitchiti Experimental Forest near Macon, Georgia, have recently been analyzed. These large-scale tests include 42 areas, each approximately 40 acres in size, that compare many-aged management with various methods of even-aged management, including clear-cutting and planting, seed-tree cutting, and shelterwood cutting. Two owner objectives are tested under these planned methods: large, high-quality products, and small products.

Two sets of controls, without any form of management except fire protection, are also included. One of the control treatments consists of no cutting; the other consists of usual sawtimber cutting practices currently being used in the lower Piedmont.

The four reserve compartments with no cutting showed remarkable growth during an 11-year period. The average annual growth per acre was 450 board feet (International ¼-inch) or 108 cubic feet, and the basal area growth of pine was 2.39 square feet per acre per year. The compartments ranged in annual growth from 327 to 610 board feet as a result of variations in sites, in the age of the trees, and in stocking. In addition, mortality ranged from 9 to 41 board feet per acre per year.

Usual practice in the lower Piedmont consists of cutting sawtimber to a variable diameter, depending largely upon the going demand and price of 4-inch-width boards and to a lesser extent upon clear bole length. Three compartments were assigned this treatment, where all currently merchantable sawtimber trees are harvested at 11- or 12-year intervals but no pulpwood is being cut nor are any cultural measures applied.

Twelve years after the first usual-practice harvest, there are again about the same number of trees 6 inches d.b.h. and larger, but their average size is now 9.1 inches, where before it was 10.4 inches d.b.h. The board-foot volume is only one-half of what it was before; the average annual production is 190 board feet, or 52 cubic feet per acre. In addition to low volume production, the quality of the lumber was poor and the quality of the residual stand is low.

In the managed stands, the initial degree of stocking overshadowed any influence that different methods of management had upon merchantable volume production. However, the tests definitely point out that maximum production will be associated with the method of management which provides the largest average merchantable growing stock throughout the life of the rotation. Other conclusions are:

1. Clear cutting and planting is most appropriate on sites where low-value hardwoods prevail.
2. Seed tree cutting is not a reliable method for regenerating loblolly pine in the lower Piedmont, because good seed years occur sporadically and frequent late spring droughts often result in complete loss of the new seedling crop (fig. 21).
3. Loblolly pine tends to form shelterwood conditions and the versatility of shelterwood management makes this method exceptionally well suited for lower Piedmont conditions.
4. Even selective cutting in the heterogeneous stands of the lower Piedmont favors high returns over at least three to four 8-year cutting cycles, and contrary to coastal plain conditions may prove to be a successful method for managing loblolly pine for quality sawtimber and pulpwood.

George Walton Experimental Forest

On the George Walton Experimental Forest 2,273 acres were delineated as a pilot-plant area in 1949. The pilot-plant study has as its principal objective the test of a system of management aimed at producing the maximum sustained yield from the property. Multiple-use management involving the production of wood, gum, and stock forage — the three basic products common to forest lands of the territory — was carried out using the best methods of management consistent with increased technical knowledge and changing market conditions.

The most important conclusions reached after 10 years of study include:

1. A forest property in the middle coastal plain of Georiga can be financially successful (over 10 percent return on the investment) under a multiple-use objective of wood, gum, and stock forage production, although wood production provides the bulk of the forest revenue.
2. A unit of this size (2,273 acres) is large enough to operate successfully as a financial venture.

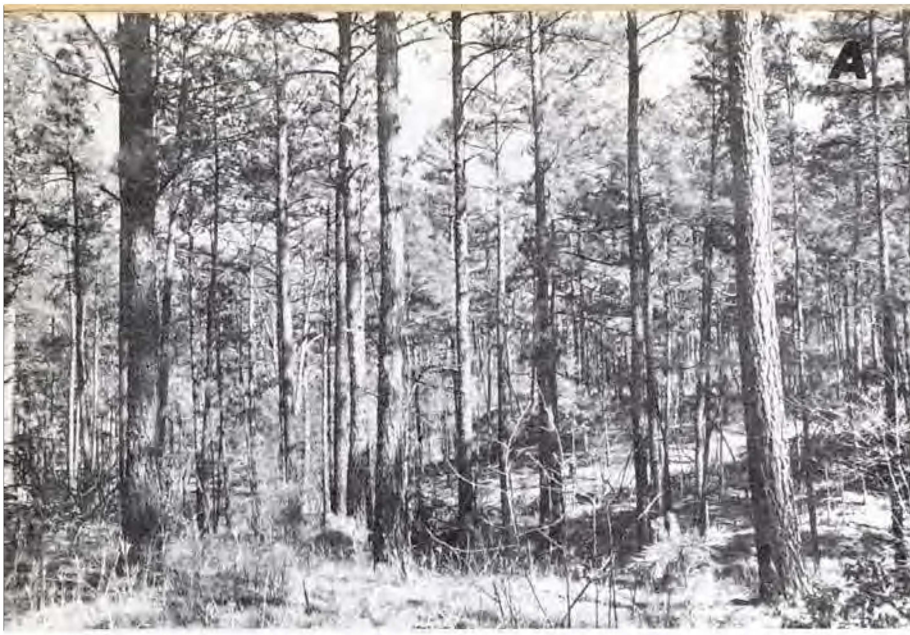
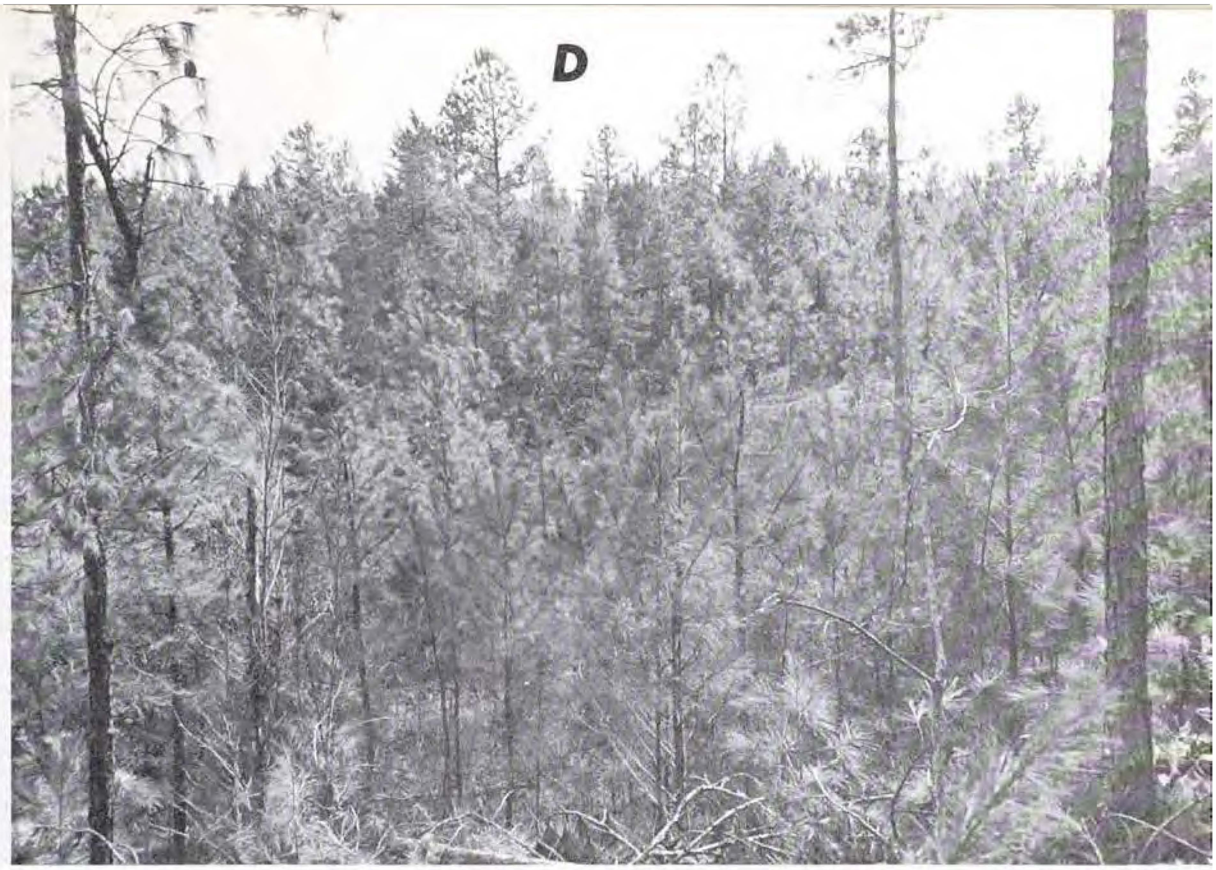


Figure 21.—One of the systems of management being tested in the Hitchiti compartment study is seed tree cutting. In 1947, after an improvement cut, this 40- to 50-year old stand had an average stocking of 50.6 square feet basal area per acre (A). A seed tree cut was made in 1951 (B). At the time of the cut, 71 percent milacre stocking was present, indicating the role of advance reproduction. Five years later, the site pictured had a 73 percent milacre stocking of vigorous loblolly pine seedlings (C). The final seed tree cut was made in 1958; the seed trees gained only 97 board feet per acre during an eight-year period (D). In 1960, the photograph of advance reproduction taken from a logging road shows the density of the naturally regenerated stand (E).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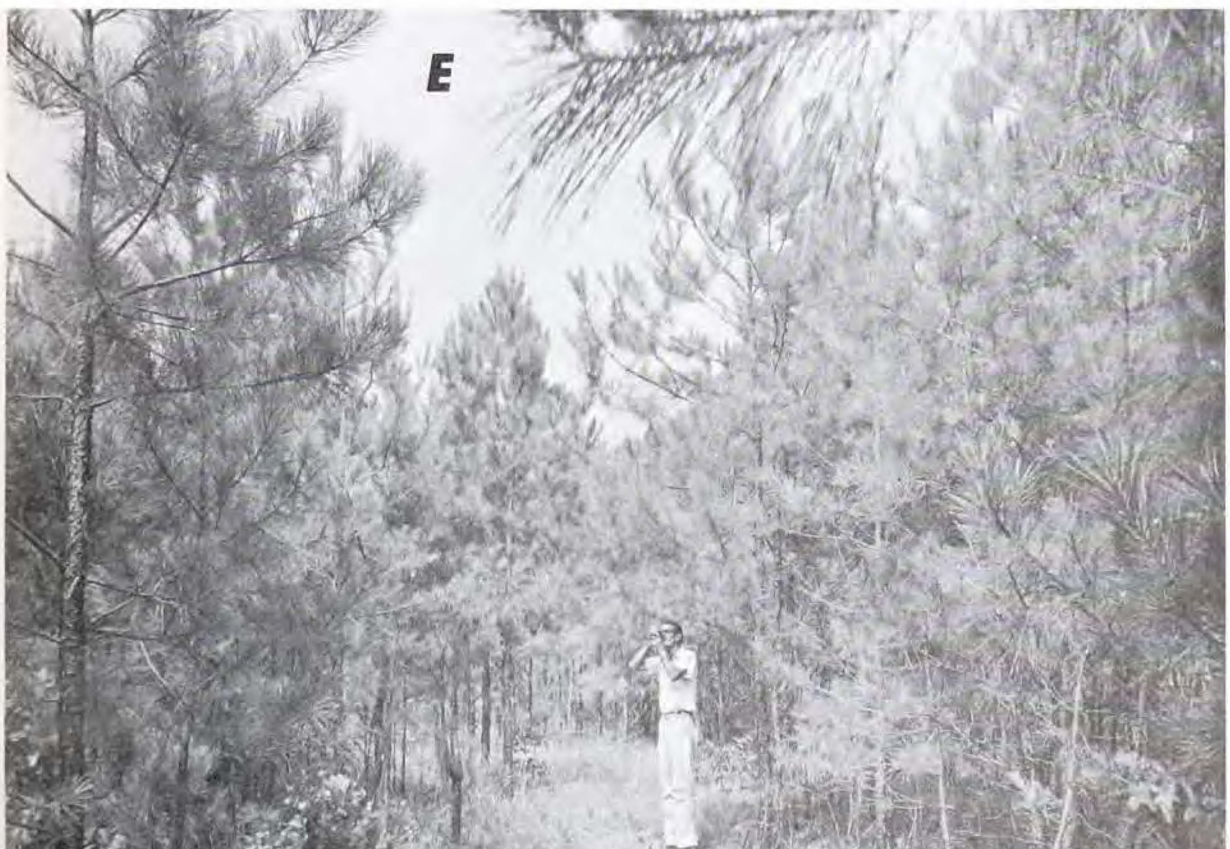
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3. As much sawtimber has been harvested over the 10-year period as stood originally, and at the last inventory, 67 percent more sawtimber was present than initially, plus almost the equivalent of the original pulpwood stocking.
4. Stand structure was continuously improved by analysis of the original stands, judicious marking aimed in part at improving the stand structure, and well planned and executed yearly operations.
5. In this section of Georgia, and using the best current management practices, slash pine aggressively crowded out the less active longleaf pine. A 2:1 ratio of longleaf to slash pine has been reduced to a 1:1 ratio without purposeful discrimination against longleaf.
6. Even with 10 years of intensive forestry, this pilot-plant barely held its own with respect to area in adequately stocked productive condition. At the beginning of operations, 70 percent of the area was adequately stocked in reproduction or merchantable acreage of desirable forest types; 10 years later, 73 percent of the area was in desirable stands. The remaining 19 percent available for forest production at this time was either inadequately stocked or was occupied by undesirable types.

PROGRESS IN OTHER FIELDS

In 1955, W. G. Wahlenberg began work on a loblolly pine monograph. Under the sponsorship of the U. S. Forest Service, southern forest industries, and Duke University, Wahlenberg completed the monograph "Loblolly Pine: Its Use, Ecology, Regeneration, Protection, Growth and Management." This 603-page treatise, published in 1960, was gleaned from the author's own years of personal experience plus a review of nearly 1,500 articles concerned with loblolly pine.

Improved extraction methods and application techniques have been developed during 15 years of research and testing at the Lake City Research Center with the cooperation of gum producers and timber owners throughout the gum naval stores belt. These methods and techniques were brought together during 1960 and published as "Modern Gum Naval Stores Methods" by Ralph Clements.

In 1959, a cooperative study was begun in north Florida and south Georgia to evaluate the effect of site preparation upon planted slash pine survival and growth. Eighty plots have been installed on cooperators' lands; they represent the ranges in site quality, and the density and composition of the ground cover found in the flatwoods. Another 80 plots will be installed each year for two more years in order to minimize the effects of annual variation in weather. Four different intensities of site preparation are being tested, including burning only, and burning plus one, two, or three passes of a heavy disk harrow. The effect on wildlife habitat is also being measured with the aid of technicians from the Georgia Game Commission and the Florida Game and Fresh Water Fish Commission.

SILVICS

Distribution of Slash Pine

The natural range of slash pine extends from southern South Carolina westward to eastern Louisiana, and southward to the Gulf of Mexico and central Florida. Seed source and racial studies indicate that slash pine is susceptible to variations in climatic conditions within and possibly adjacent to its natural range.

In a "Forest Science" contribution, Bethune studied the relationship of temperature and precipitation by seasons and average length of the frost-free period to the natural distribution of slash pine. He used seasonal rainfall to develop a distribution line based on climatic factors which closely paralleled the actual distribution of slash pine.

Areas of South Carolina, Georgia, Alabama, Mississippi, and Louisiana outside but adjacent to the northern limits of natural distribution of slash pine appear suitable climatically for the species (fig. 22). Other areas in these same states that are farther removed from the natural range, but where slash pine is now being planted, may lack sufficient frequency of heavy rains; planting of slash pine in these areas should be undertaken with caution.

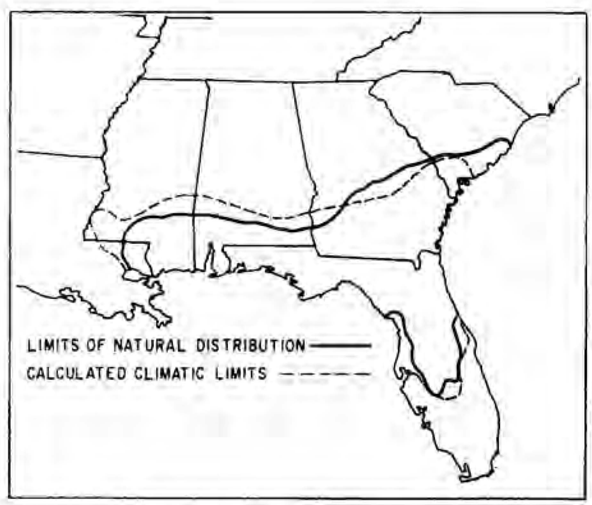


Figure 22.—Map showing the limits of natural distribution of slash pine and the calculated climatic limits.

Prescribed Burning in the Coastal Plain

More than a decade of study in the South Carolina coastal plain has determined that, for understory hardwood control, the best results with prescribed fire are obtained in loblolly pine stands where the ground is covered with a continuous mantle of fuel consisting mainly of fallen pine needles and similar fine material. Furthermore, most of the understory stems should be under 2 inches d.b.h., because larger stems can escape control by fire. Depending on the degree of control desired, a forest manager can use either winter or summer fires. The winter fires won't kill many of the hardwoods, because most resprout regardless of the frequency of burning. From a practical standpoint, however, winter burns can be spaced about 5 to 10 years apart and the understory thus held to small-sized stems subject to further control by fire as needed. The best use of a short series of summer fires is for hardwood eradication and seedbed preparation about the time of the harvest cut (fig. 23).

Experienced personnel can prescribe burn small tracts for less than fifty cents per acre. Consequently, a full schedule of winter and summer fires for hardwood control and seedbed preparation would cost about $5.00 per acre over a sawtimber rotation. There is little to fear regarding possible damage from well-planned and well-executed prescribed fires in coastal plain loblolly pine stands above sapling size. Damage to the pine stand from an intense summer burn is avoided by fuel reduction obtained from prior winter burns. Intensive plot studies show that prescribed burning causes no significant difference in the radial growth of dominant pine in any season, even after 10 consecutive annual fires.

Significantly, prescribed burning does no damage to the typical sandy loams of the coastal plain loblolly pine sites. No ill effects to the soil were measured over 10 years of plot studies which included annual winter and summer fires (10 each) and winter and summer fires at irregular intervals of three or more years (2 each), as compared to no fires during the period.

Control of Honeysuckle and Kudzu

Japanese honeysuckle and kudzu were introduced from Asia for horticultural purposes and during the Civilian Conservation Corps days they were used for roadbank fixation. Kudzu has been used successfully for gully control, meadow strips, and temporary pastures. Both vines escaped from cultivation and now seriously inhibit the establishment of pine and hardwood seedlings throughout substantial areas in the South.

The spread of honeysuckle and kudzu and the difficulty in controlling them led to studies on their behavior and control at Macon, Georgia. They included tests with grazing, fire, harrowing, application of herbicides, and combinations of these treatments. Three of 17 herbicides tested provided control when applied under proper conditions. Butoxy ethanol ester of 2, 4-D (ACP 685) and 2, 4, 5-T in a 2:1 ratio, 2 pounds acid equivalent per gallon in 65 gallons of water, applied twice as a spray during the growing season gave good results. Amino triazole and Amitrol-T also gave good results but should not be applied on lands used for food-crop plants or livestock forage.

Slash Pine Spacing and Thinning

The age at which competition begins in slash pine plantations is one of the factors which influences the forest manager in his spacing decision. A slash pine study recently completed on the George Walton Experimental Forest near Cordele, Georgia, established relationships between plantation spacing and competition.

Tests indicated that competition developed at a density of 500 to 550 trees per acre during the fifth growing season in the field and had an increasing effect during the sixth and seventh years. An example of the increasing effect of stand density is the expanding difference between the mean diameter of a 15 x 15 spacing and a 6 x 6 spacing (table 4). Trees spaced 15 x 15 were only 4 percent larger than those spaced 6 x 6 at the end of the fourth year but over 23 percent larger at the end of the fifth year.

Height growth was not correlated with stand density, but the crown ratio percent after 7 years was in direct proportion to crown density.

The density that slash pine stands should be thinned to has always been a problem because stand reaction to release has not been measured.

Table 4.—Difference in the average diameter of planted slash pine with 6 x 6 and 15 x 15 spacing at various ages

Age (Years)	Spacing		Difference	
	6 x 6	15 x 15		
	- - Inches - -		Inches	Percent
4	1.49	1.55	0.06	4.0
5	2.45	3.02	.57	23.3
6	2.97	3.96	.99	33.3
7	3.39	4.74	1.35	39.8

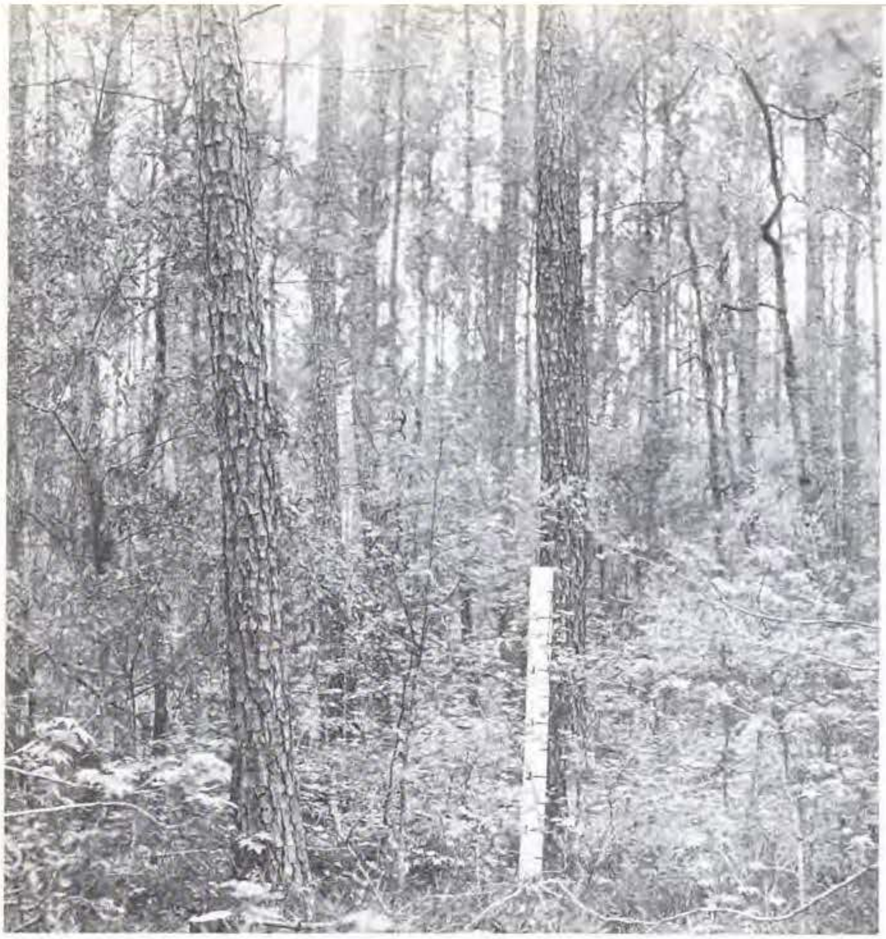
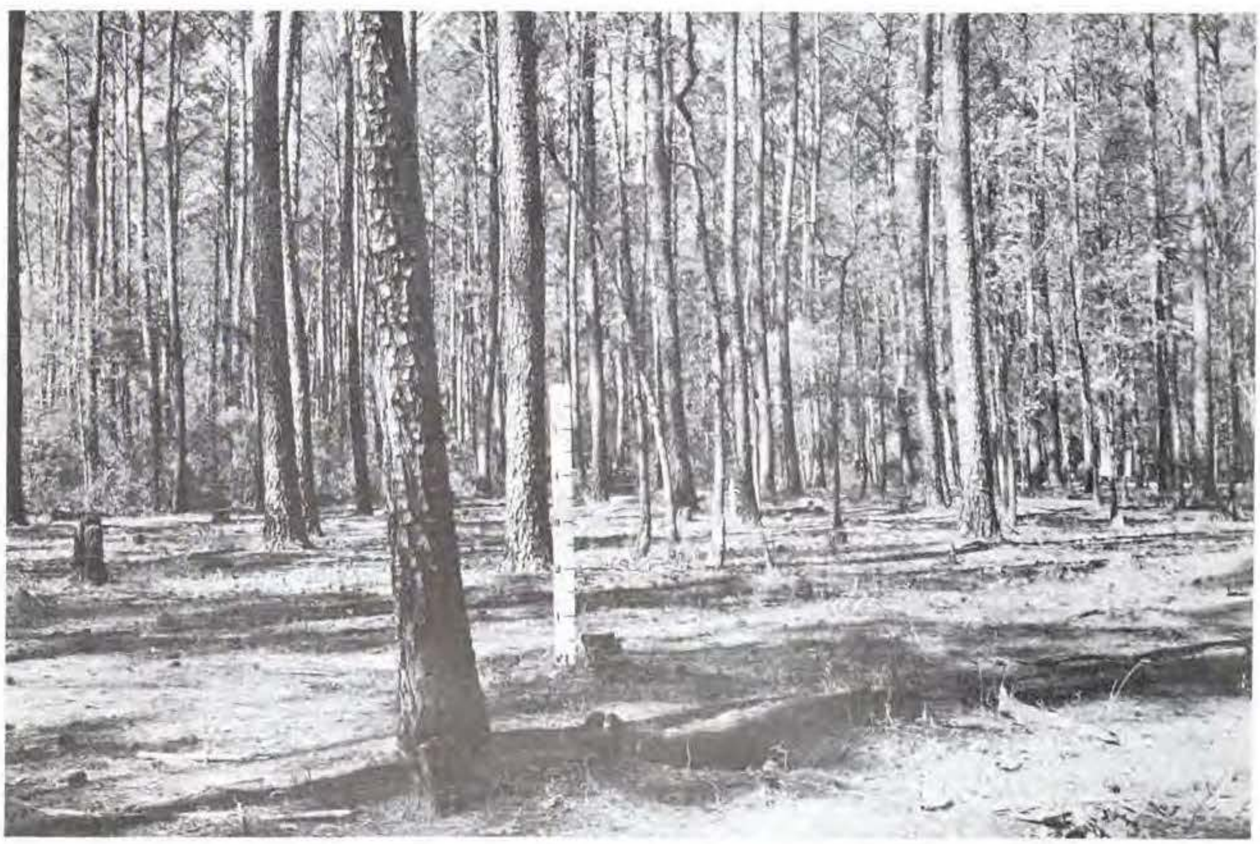


Figure 23.—Annual summer fires can eradicate hardwood understory in loblolly pine stands of the coastal plain. Upper photo shows stand with one improvement cut before fire. The lower photo was taken 10 years later after three improvement cuts and annual summer fires. Such drastic treatment is not necessary. A short series of summer fires will eradicate hardwood understory and prepare a good seedbed.



Data presented by Frank A. Bennett in a recent article in the Journal of Forestry point out that after a certain age crown length cannot be appreciably increased through additional height growth. This in turn means that the crown ratio percent — one of the main opportunities for increasing crown area and subsequently the response to release — cannot be materially increased by release (fig. 24).

Prior to age 30, slash pine response to thinning through increase in crown ratio is good, but after age 30, and especially after age 35, the response is negligible.

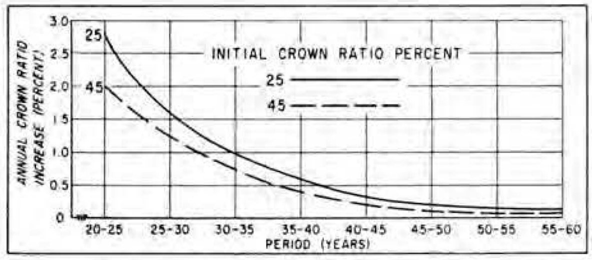


Figure 24.—Periodic annual increase in slash pine crown ratio percent after thinning at initial crown ratios of 25 and 45 percent.

TREE BREEDING AND IMPROVEMENT

In the field of genetic improvement of trees, large amounts of important data are becoming available from plantings made over the years. Our racial variation studies of major pine species are scattered from south Florida to Virginia, and most of them are 5 to 13 years old. Thus, the pattern of growth is fairly well established. Analysis of these data is continuing.

Valuable heritability data for many important traits have been computed in Georgia and Florida from 8-year-old and 14-year-old progeny tests and will be published soon. Data of this kind are invaluable for planning selection and crossing work in the future not only by research people but tree breeders in forest industry.

Figures 25, 26, and 27 show some of the work in progress at Lake City.

To get our results into practice and help the tree planter, work continues in seed production area establishment, seed orchard establishment of improved strains, and in the field of seed certification. Several thousand seedlings from controlled crosses of plus tree clones within the Georgia Forestry Commission's grafted seed orchard are ready for outplanting in the fall of 1961 for progeny tests. Thus, seed production will commence shortly in grafted seed orchards established by the Southeastern Forest Experiment Station in Florida and in cooperation with the Georgia Forestry Commission and the Ida Cason Callaway Foundation in Georgia. Suddenly, forest tree breeding work — which to many has seemed of theoretical interest because of the long time required for results — has moved into a very realistic stage by producing data and superior strains of trees for foresters to use.

NAVAL STORES

Increased interest in naval stores operations was again apparent during 1960. In addition to the gum naval stores manual, other naval stores studies reached culmination. One study obtained gum yields for plantations and provided a comparison of these yields with natural stand yield tables.

During the first three years of work, average yields of planted stands showed little variation from those of natural stands (table 5). The small variations observed are probably attributable to differences in chipping. The similarity in production between the two types of stands suggests that, for the three seasons involved, age and site did not influence gum yields.

The plantation study also indicated that if we accept 200 barrels per crop (8.7 pounds per tree) as the minimum acceptable yield, then 32.5 percent of the 9- and 10-inch trees in this test and 11 percent of the 11-inch trees produced at a rate below cost level and were worked at a loss.

Table 5.—Comparison of gum yields for plantations and natural stands of slash pine

D. b. h. class (Inches)	Crown-length ratio 1/	Seasonal yield per crop	
		Plantations	Natural stands
	Percent	- - - Barrels - - -	
9	49	211	205
10	51	247	241
11	55	282	285
12	56	318	319
13	59	353	357

1/ Since crown-length ratio is a variable in the natural stand yield table, it is included here to provide accurately interpolated yields for the natural stands. Yields are based on $\frac{5}{8}$-inch streaking, the accepted standard at time of installation of study.

Figure 25.—Control-pollinating a superior slash pine.

Figure 26.—This unique plantation at Lake City, Florida, contains 550 slash pines 15 years old, bred from superior selections. Several of these trees yield three times as much gum as average slash pine, others grow nearly twice as much wood as average, and still others have outstanding characteristics such as high or low specific gravity, long or short fibers. Second-generation progeny are now being produced in order to create still better strains having different combinations of these valuable traits.

Figure 27.—A plantation of rooted air-layers from 12 high-gum-yielding slash pine trees and 12 average. The air-layers were made on progeny of trees selected for gum yield. The plantation was established to find out effects of irrigation, cultivation, fertilization, and leguminous ground cover on tree growth and gum yield.

FOREST UTILIZATION

The Division was able in 1960 to intensify studies of wood quality. One important step was formal recognition of the southern softwood log and tree grade project, with the addition of a full time Project Leader to the Asheville staff.

Weight-Volume Relation of Southern Pines

A field study completed this year was designed to answer questions about buying round southern pine products by weight and relating the weights to volume measurements. The data can be used by buyer or seller to check on weight-volume conversions. Figures 28 through 31 show some details of study techniques and practical uses of the results.

Figure 28.—A cooperative study with the Georgia Forest Research Council and the Georgia Forestry Commission developed useful information on the weight per cubic foot of the four southern pines and the weight of logs necessary to saw 1,000 feet of pine lumber.

Figure 29.—Weight is influenced by the specific gravity, which in turn varies with springwood and summerwood in the annual ring.

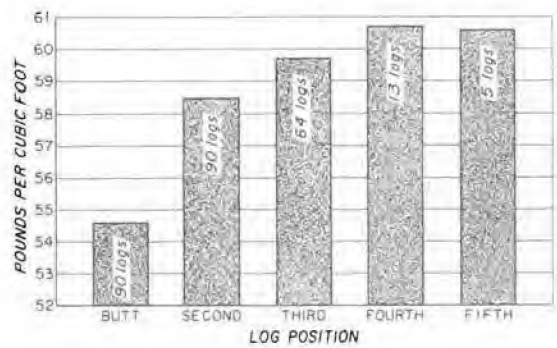


Figure 30.—The weight per cubic foot of wood increases toward the top of the tree. Although the specific gravity becomes lower, the amount of sapwood and the moisture content increase; therefore, the net effect is more weight toward the top. The above shows an over-all average. There are important variations by species and indications of variations by different locations in Georgia.

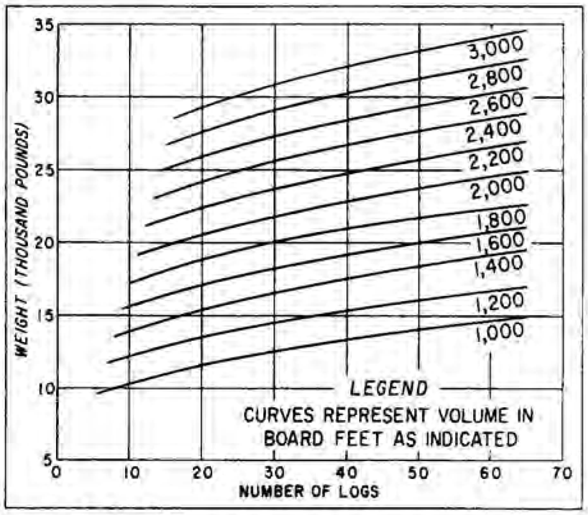


Figure 31.—Using all data collected and basing results on average mill practices and average efficiency of operations, it was possible to develop graphs like that above, permitting an estimate of the board feet of lumber that can be produced from a truckload of green logs when the total weight, number of logs, and length of logs are determined. This particular table applies to truckloads of 16-foot loblolly and shortleaf pine logs.

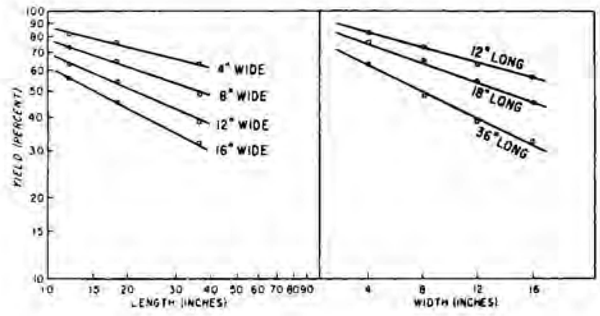


Figure 32.—The relationship between width of clear veneer cutting and the logarithm of percent yield of clear veneer, as well as the relationship between bolt length and the logarithm of percent yield of clear veneer were found to be linear as indicated in the above graphs for bolts free of surface defects. The same relationships prevailed for five other bolt classes where defects were confined to 1 quadrant surface, 2 adjacent quadrant surfaces, 2 opposite quadrant surfaces, 3 quadrant surfaces, and 4 quadrant surfaces.

Hardwood Veneer Log Grading

During the past several years, studies were undertaken in cooperation with the North Carolina State College School of Forestry to develop rational grades for hardwood veneer logs. These studies involved the development of a sampling plan, data collecting procedures, grading systems, and an electronic computer program for processing veneer log grade data. Although the work is still continuing, some of the results are worthy of consideration at this time. Among these are: the relationships of width and bolt length combinations of clear veneer cuttings to percent yield of clear veneer, which are shown in figure 32, and the yield of clear veneer as affected by size of veneer bolt and distance from bolt center (radius), shown in figure 33. An analytical technique and program for processing and analyzing veneer log data in a number of ways have been developed for use with an IBM-650 Magnetic Drum Digital Computer. Programming details are available at the North Carolina State College School of Forestry, Raleigh, N. C.

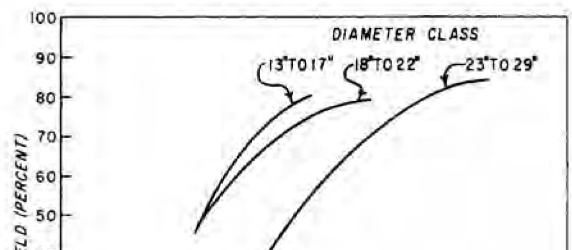


Figure 33.—Relationship between yield of clear, 4-inch-wide veneer cuttings 36 inches long for 3 different diameter classes of logs free of surface defects. The above graph shows that on the average, the sheath of clear veneer on the outside of mill-run veneer logs is usually about the same thickness, regardless of log diameter.

A Physicochemical Study of Wood Charcoal Produced In Cinder Block Kilns

In 1959, the Station entered into a cooperative project with the Chemistry Department, University of Georgia, to investigate the basic chemical properties of unactivated kiln charcoal. Samples from two kiln charges each of oak and sugar maple, and one each of pine and mixed southern hardwoods were compared with a commercial activated charcoal. The following tests were conducted: bulk density, true density, sieve analysis, elemental analysis, pH of water extract, iodine test, permanganate test, moisture content, adsorption isotherms, and desorption isotherms.

The "unactivated" charcoal samples tested showed a relative efficiency (compared to activated charcoal) of 11 to 21 percent in their ability to adsorb odors; 0 to 18 percent in their ability to adsorb colloids; 10 to 80 percent in removing organic substances from liquid media; favorable in adsorbing inorganic substances from liquid media; 30 to 50 percent in adsorbing gases from gaseous media. The desorption rates were much faster than for activated samples.

The desorption isotherms for methyl bromide and chloropicrin are shown in figures 34 and 35.

The data lead to some interesting possible uses for kiln charcoal as a safe soil-treatment carrier of herbicides, fungicides, or insecticides.

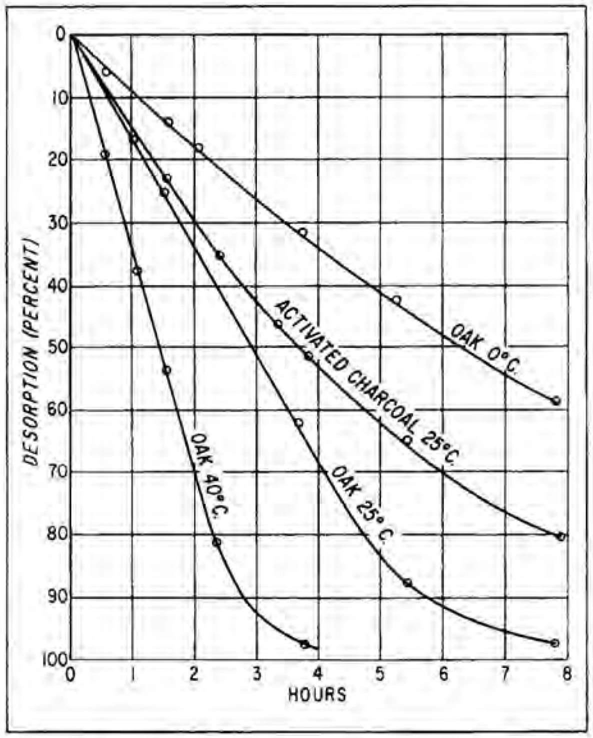


Figure 35.—Desorption rate of chloropicrin at different temperatures in activated charcoal and charcoal made from oak.

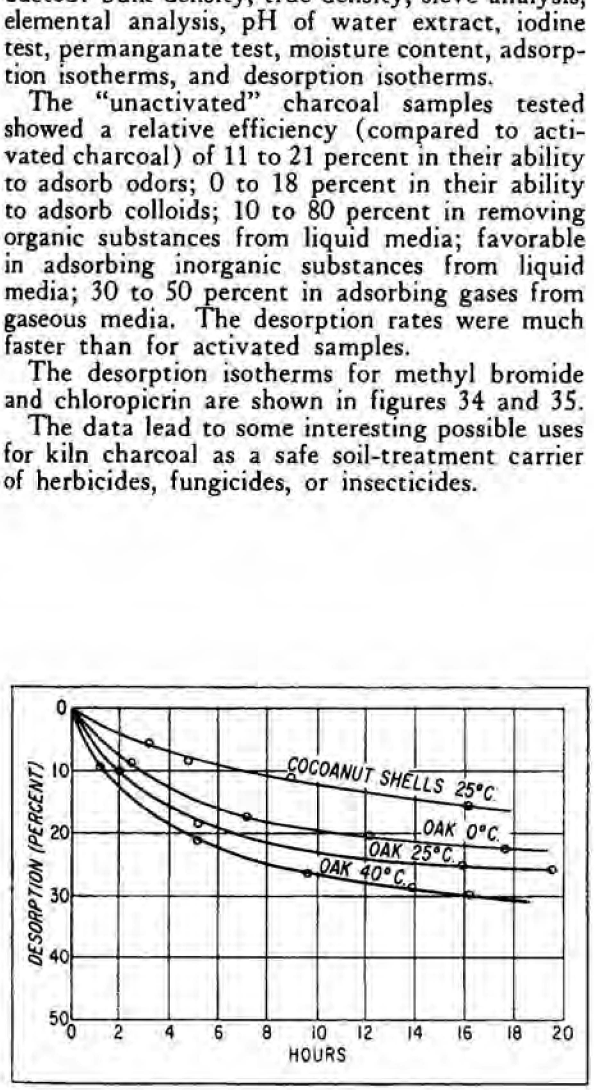


Figure 34.—Desorption rate of methyl bromide at different temperatures in charcoal made from oak and cocoanut shells.

The Relationship Between Gamma Ray Absorption and Wood Moisture Content and Density

In cooperation with North Carolina State College School of Forestry, a study was made to evaluate gamma radiation technique for measuring specific gravity and moisture content of wood. Gamma ray absorption was measured on yellow-poplar blocks conditioned at 5 different moisture contents with specific gravities ranging from 0.31 to 0.53. The linear absorption coefficients at known moisture levels (X_2) were compared with their corresponding specific gravity values (X_1) (fig. 36).

This study disclosed that when the gamma ray attenuation, the thickness of the wood, and the moisture content are known, the specific gravity of wood can be determined by this nondestructive technique rapidly and with a high degree of accuracy. When gamma ray attenuation, thickness, and specific gravity are known, moisture content can be determined in its complete range.

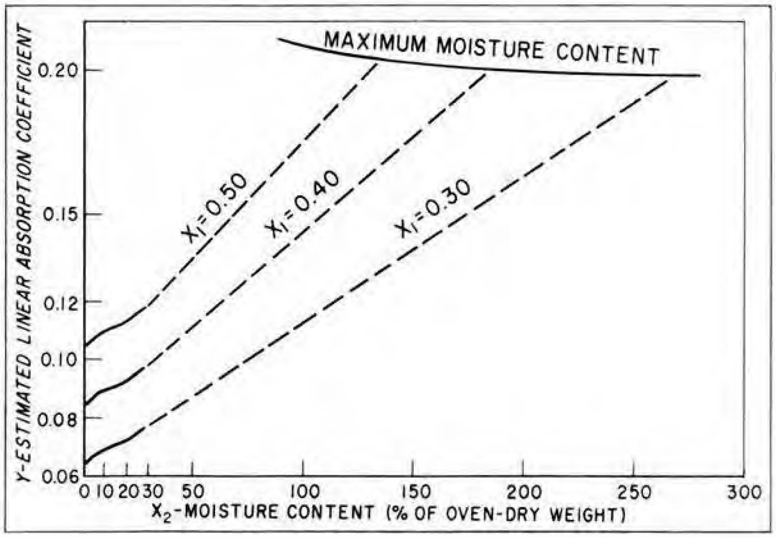


Figure 36.—The relationship between three specific gravity levels (0.30, 0.40, and 0.50), moisture content, and estimated linear absorption coefficient.

Building Homes To Withstand Hurricanes

Hurricane Donna spread destruction in early September from Puerto Rico to Labrador, taking 142 lives, injuring 1,388 people, destroying 2,814 homes, and severely damaging 52,954 others.

Much of this loss is needless and could be avoided by commonsense practices in home and building construction. Figures 37 through 41 are views of structural strength and weakness along the Carolina shore soon after the hurricane.

Figure 37.—Foundations should be properly driven or tied into the ground and adequately braced, as shown in the house above. (Left), Tying to a cement block doesn't accomplish much if the block moves with the house.

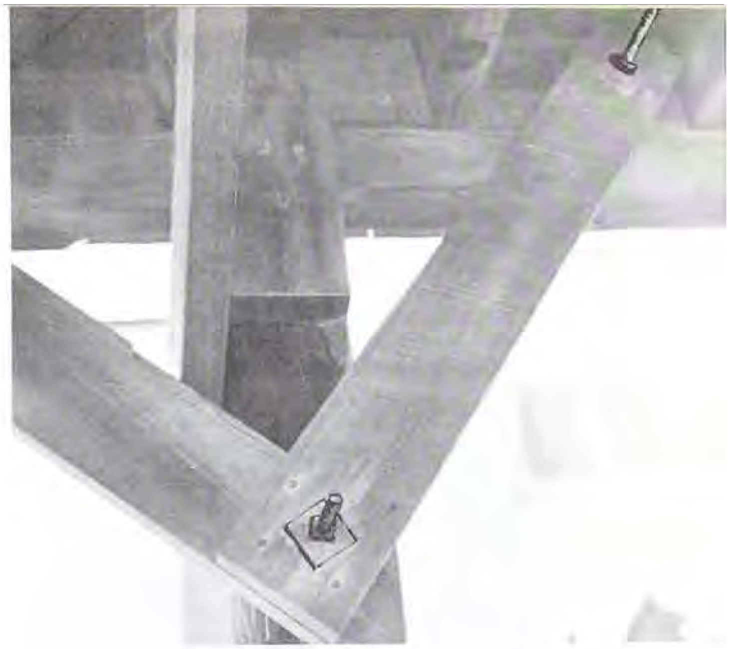


Figure 38.—(Above), Foundation piling should be well braced and tied to floor sills and cross bracing with bolts. (Left), Toenailing sills to piling is not enough.

Figure 39.—Siding should be of wood, either as boards or shingles, well nailed and preferably over diagonal wood sheathing. (Above), This row of well built wooden houses has withstood at least four major hurricanes. (Left), Wreck of a non-wood house.

Figure 40.—(Left), The roof must be well tied to a structure that is firmly built. (Right), The lack of good roof ties can be the undoing of an otherwise well constructed home.

Figure 41.—One of these houses is of good material put together according to sound principles of construction. Donna searched out the weakness of the other.

FOREST DISEASES

Diseases affecting our high-value plantings of southern pines continued to hold their places in the forefront of the disease picture during 1960. Two factors are largely responsible for this situation: (1) the intensive management of large acreages planted to southern pines in the Southeast, and (2) the threat of extensive losses where these monocultures of southern pines have created conditions favorable for the development and spread of diseases.

A survey carried out during the past year revealed that losses in thinned slash pine plantations because of annosus root rot were much more widespread than we had previously realized (fig. 42). Recent reports show that loblolly and longleaf pines are also susceptible to this disease.

Fusiform rust remains as a constant source of loss to our nursery seedlings, if unsprayed, and to young growth in both plantations and natural stands in a broad belt across the South (fig. 43). Rust has also infected many of the trees in some seed orchards. These grafted, high-value trees represent our best hope for improved nursery stock in the future, and their loss is a serious setback in this program.

Annosus Root Rot

Studies are under way to follow the course of infection and spread of *Fomes annosus* in both white and slash pine stands. Following the first thinning, the disease established itself in each of the eight previously disease-free white pine stands under study in western North Carolina. Killing and windthrow because of rotted roots have occurred in one white pine stand 4 years after thinning (fig. 44). In slash pine stands, as well as in white pine, thin crowns and turpentine beetle attack are useful indicators of annosus root rot infection.

The effectiveness of creosoting fresh stumps to prevent stand infection is also being studied. It is too early for results from slash pine stands, but creosoting reduced the percentage of stumps infected with *F. annosus* in two white pine stands from an average of 17.5 percent of the untreated group to 2.5 percent of the treated stumps.

A survey for annosus root rot in slash pine stands was carried out during March 1960. The survey was confined to South Carolina, Georgia, and Florida, and the disease was found to be widely distributed throughout this area. Some trees were being killed by annosus root rot in 73 percent of the thinned slash pine plantations examined (fig. 45). Unthinned plantations were much less diseased, with only 9 percent of the stands having any trees killed by the disease. The extent of losses was highly variable, depending largely on the time lapse since thinning. Natural stands of slash pine were generally sustaining lower losses than plantations, and again most of the killing by *F. annosus* was found in thinned stands.

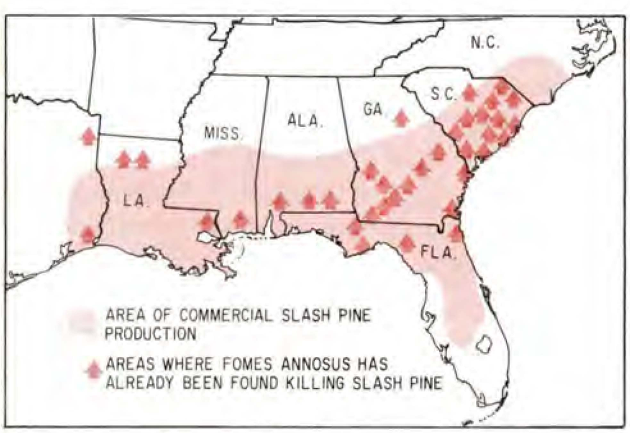


Figure 42.—Thinned slash pine has been attacked by F. annosus throughout the entire area where it is grown commercially.

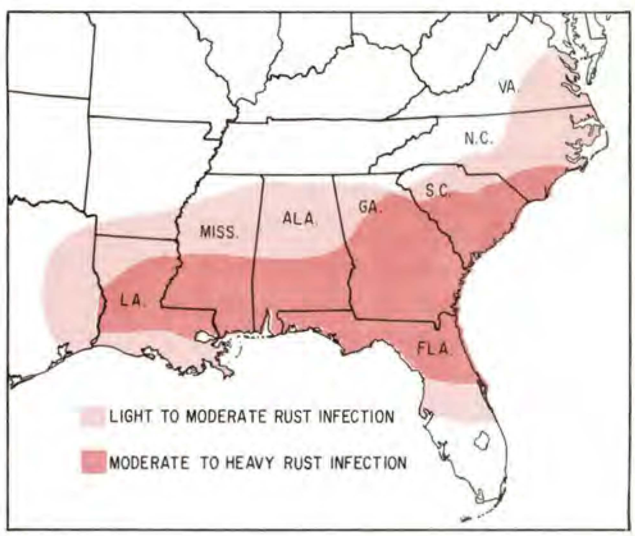


Figure 43.—Zones of fusiform rust severity.

Reports of damage to planted loblolly pines by annosus root rot have increased this year, but are still far fewer than those concerning slash pines. Loblolly pines have been reported dying in several locations, ranging from the eastern shore of Maryland, through North and South Carolina, Alabama, and over to east Texas.

Figure 44.—Conks of Fomes annosus under needle litter at base of infected white pine.

Figure 45.—Slash pines killed by Fomes annosus in a thinned 20-year-old plantation in South Carolina.

White Pine Blights

Work on another very difficult problem, white pine blight, is producing answers as to the causal factors behind this disease complex. One type of needle damage has been linked to industrial fume injury, while the origin of a second type of damage in the blight complex appears to lie in atmospheric factors unrelated to fumes.

Investigation has revealed that, aside from needle diseases of fungus origin, two distinct symptom complexes exist, and each suggests different causal factors. One type of injury, now called emergence tipburn, occurs only in the summer on new needles, and may be found wherever white pine grows. This type of injury was previously called white pine needle dieback or needle blight. An experiment carried out in West Virginia, where emergence tipburn is prevalent, has further substantiated the belief that above-ground factors are involved. Twigs on 15 diseased trees were covered with both plastic and paper bags from March 15 to May 11. The protected twigs on 13 of the 15 diseased trees bore new needles that were either free from tipburn or had reduced tipburn symptoms. Uncovered twigs on tipburn trees bore new needles that developed tipburn.

The second disease complex has been termed post-emergence tipburn and involves such symptoms as mottling, chlorosis and tipburn of the needles, reduced shoot growth, and often death of trees. This damage may occur at any time of the year and has been observed only in association with industrial fumes. Post-emergence tipburn on white pine has been observed each year since 1957 in parts of eastern Tennessee, and on plots established in this area 10 percent of the 160 dominant and codominant trees have died since 1957. Even more serious damage to white pine was observed around certain industrial areas in Pennsylvania during 1960. In the immediate vicinity of one plant, white pines had been eliminated. The damage gradually decreased with increasing distance from the plant, so that 20 miles away disease symptoms were almost absent.

Cone Rust

Additional information has been gained about the most effective means of controlling cone rust, caused by *Cronartium strobilinum*, a disease which seriously reduces the seed crop of slash and longleaf pines in the deep South. Ferbam, at a concentration of 2 pounds per 100 gallons of water, gave almost perfect control of rust in three spray trials carried out during the past year. Another experiment showed that conelets are most susceptible to rust infection in stages 1 through 3; therefore, spraying must begin at the time of strobilus emergence and continue until after pol-

lination has occurred. A spray program based on a regular schedule, rather than on weather prediction, is recommended at this time. Spraying every five days gave control equal to spraying immediately before predicted periods of high humidity or rain, and eliminated the uncertainty involved in weather prediction and the ensuing hurried spray applications.

Mycorrhizae of Southern Pines

New concepts and techniques have resulted from the study of mycorrhizae on southern pines. One of the most important of these is the possibility that mycorrhizal fungi may ward off attacks on pine roots by soil-borne disease organisms such as the littleleaf pathogen. Tests have been carried out with the littleleaf pathogen, *Phytophthora cinnamomi*, and several known mycorrhiza-forming fungi. Different degrees of antagonism were noted when *P. cinnamomi* was grown on agar in combination with a number of mycorrhizal fungi (fig. 46). In some cases the pathogenic *P. cinnamomi* completely outgrew the mycorrhizal fungi. When *P. cinnamomi* was grown with a *Boletus* spp., a *Lactarius* spp., and with *Clitocybe laccata*, however, the growth of the pathogen was sharply reduced.

Preliminary tests with pine seedlings illustrate the possible importance of these investigations. Newly emerged shortleaf pine seedlings were aseptically planted in a nutrient-vermiculite medium in large flasks. A mycorrhiza-forming fungus was introduced into half of these flasks, while the remainder was left uninoculated. Three months later, inoculum of *P. cinnamomi* was planted in all flasks. After three months' subsequent growth, seedlings grown with mycorrhizal fungi plus *P. cinnamomi* were well developed, vigorous, and bore mycorrhizae on their roots. In contrast, seedlings grown with *P. cinnamomi* alone were weak, chlorotic, and lacked mycorrhizae (fig. 47). Although these results are encouraging, more extensive tests will be needed to fully verify this phenomenon.

A recent success in isolating and identifying mycorrhizal fungi directly from mycorrhizal roots represents a significant advance in the study of these complex relationships. Twelve percent of the 212 mycorrhizae plated out yielded positive cultures (fig. 48). Five different species of fungi from the mycorrhiza-forming group were included among these cultures.

Figure 46.—(A), Inhibition of *Phytophthora cinnamomi* when grown with mycorrhiza-forming *Boletus*. (B), *Phytophthora cinnamomi* outgrowing *Amanita*, another mycorrhizal fungus.

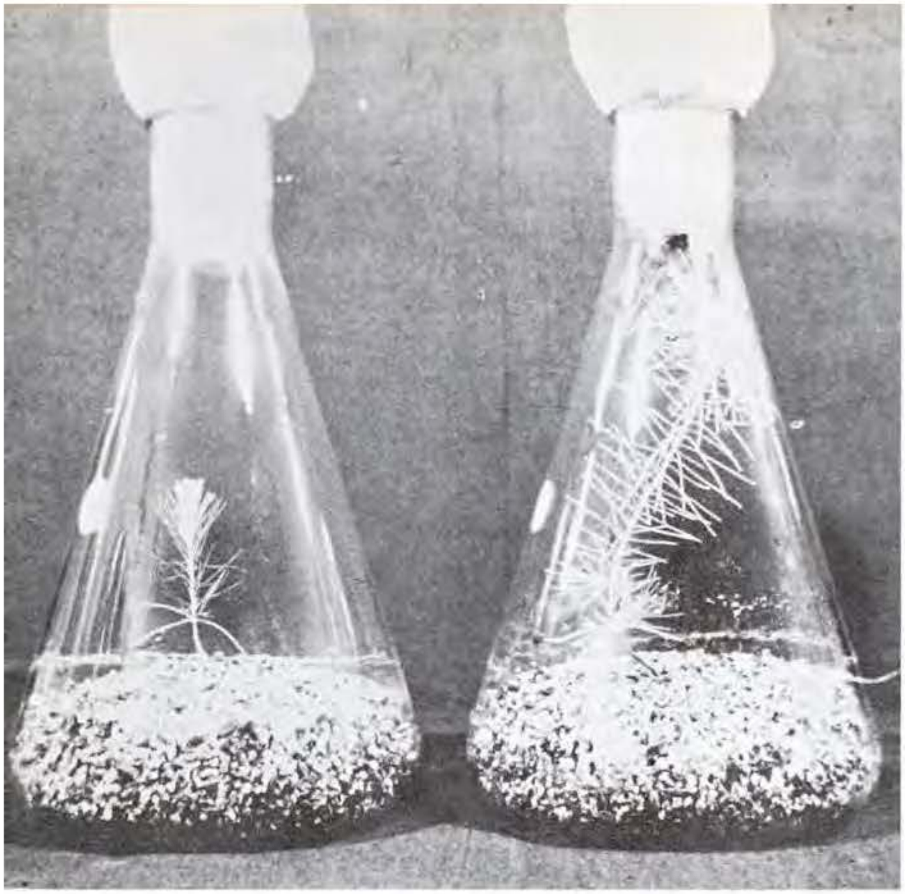


Figure 47.—Contrast between seedlings inoculated with the littleleaf pathogen alone (left) and with the littleleaf pathogen and mycorrhizal fungus (right).

Figure 48.— Mycorrhiza-forming fungus growing directly out of mycorrhizal root.

Nursery Diseases

Past research on nursery diseases has paid off manyfold by making it possible to produce healthy and vigorous seedlings in seedbeds virtually free of weeds in nurseries throughout the Southeast. The continuous cropping of pines in our nurseries, however, creates a situation favorable for disease development, and we must constantly guard against new pathogens. For example, a new disease affecting longleaf pine seedlings was first seen during the past year. This disease, needle blight caused by *Rhizoctonia solani*, was found in one North Carolina and two South Carolina forest tree nurseries in 1960. The disease was first noticed following a prolonged cool, wet period in August. Infection usually took place just above the needle sheath, and spread up the needles and down into the needle fascicles, finally killing the bud and root crown. In the North Carolina nursery, 100-percent mortality occurred in several patches 4 to 6 feet in length. The dead needles in these areas of high mortality were matted together by the fungus mycelium. A point of particular interest was that Sonderegger pine present

in the most seriously diseased portions of the longleaf beds appeared to be completely resistant to the disease. Good control of the disease was obtained by clipping the needles with a rotary mower, allowing for better aeration, and drenching twice with Terraclor at the rate of 50 pounds per acre.

Further research on the serious nursery root rot problem in the Southeast has provided additional information for diagnosis and control. Three distinct types of root rot occurred in this area during the past year: the common black root rot, which is caused by two fungi working together; a second type of rot caused by a combination of fungi and parasitic nematodes; and a third type caused by nematodes alone. All three can be controlled by methyl bromide, Brozone, Mylone, or Vapam. Where nematodes alone are involved, however, a more economical control can be obtained by using a nematocide, such as EDB, DD, or Telone.

An unidentified species of dodder (*Cuscuta*) recently was found attacking seedling needles of South Florida slash pine (*Pinus elliottii* var. *densa* Little and Dorman) growing on Big Pine Key south of the Florida mainland (fig. 49). Although dodder is a common parasite on many economic plants, this is believed to be the first report of dodder parasitism on pine.

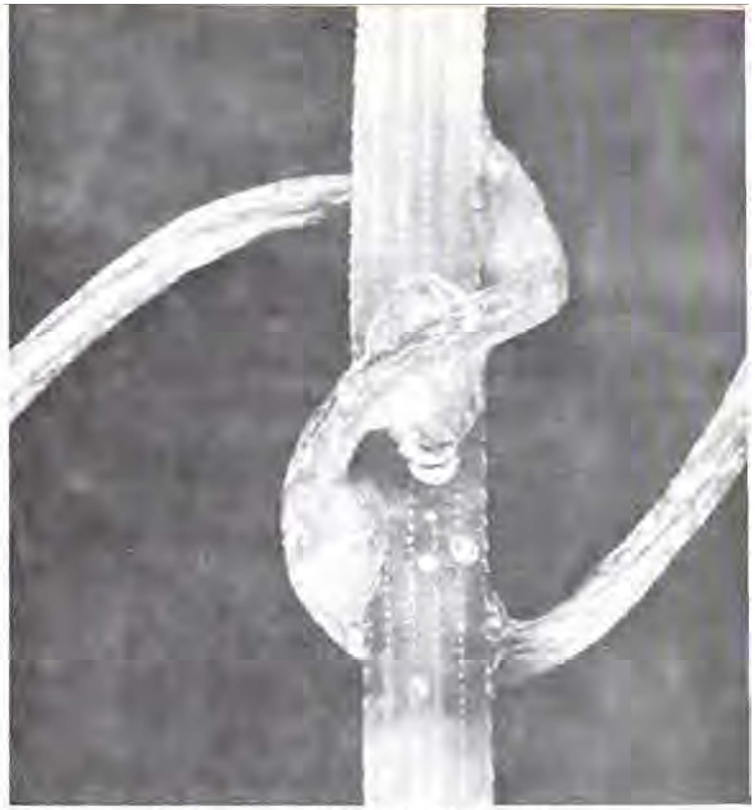


Figure 49.—Parasitic seed plant (dodder) attacking needle of South Florida slash pine.

Forest Nematology

A completely new field of research has been opened with studies in the field of forest nematology. Plant parasitic nematodes have been demonstrated to be the primary factors involved in the stunting of outplanted pines in many sandy sites in southeastern North Carolina. This stunting of planted loblolly and slash pines was associated with the presence of the lance nematode, *Hoplolaimus tylenchiformis*, and the pine cystoid nematode, *Meloidodera floridensis*. Greenhouse tests showed that these nematodes fed and reproduced on these two species of pine. In pathogenicity tests, lance nematodes were found to be very destructive and particularly reduced height growth. Pine cystoid nematodes caused considerable root damage but did not impair growth as seriously as did the lance nematode. Histological studies of loblolly and slash pine roots infected with lance and pine cystoid nematodes revealed that both nematodes are endoparasites capable of causing considerable internal damage to both lateral and mycorrhizal roots (fig. 50).

It was also found that on many sandy sites in southeastern North Carolina plant-parasitic nematodes (mainly lance and pine cystoid) indigenous to the outplanting site itself were responsible for poor seedling growth, and not the nematode species transported from the nursery on planting stock. Stunting of pines in the field, however, is believed to be much more complex than a simple case of nematode damage alone. Many environmental factors, as well as other soil-borne pathogens, probably contribute to this problem. The two species of nematodes mentioned, however, are considered the primary factors responsible for the stunting of pines planted on many sandy sites in southeastern North Carolina. This work will open new avenues of research into the complex area of soil-borne diseases, and the relationships between various pathogens and their hosts.

Antibiotic Research

The success obtained with antibiotics in controlling some tree diseases suggested testing them for control of fusiform rust of southern pines and blister rust on eastern white pine. Phytoactin, Acti-dione, and several cycloheximide derivatives have been used in these tests. Some of these tests have been in effect for 3 years and valuable information has been gained about methods of application, dosages, carriers, and phytotoxicity of the antibiotics. To date, however, no evidence has been found that any of the antibiotics included in the tests have given a measurable degree of control of either fusiform rust or white pine blister rust. It is still hoped that some modifications of application methods may yield practical control of these diseases.

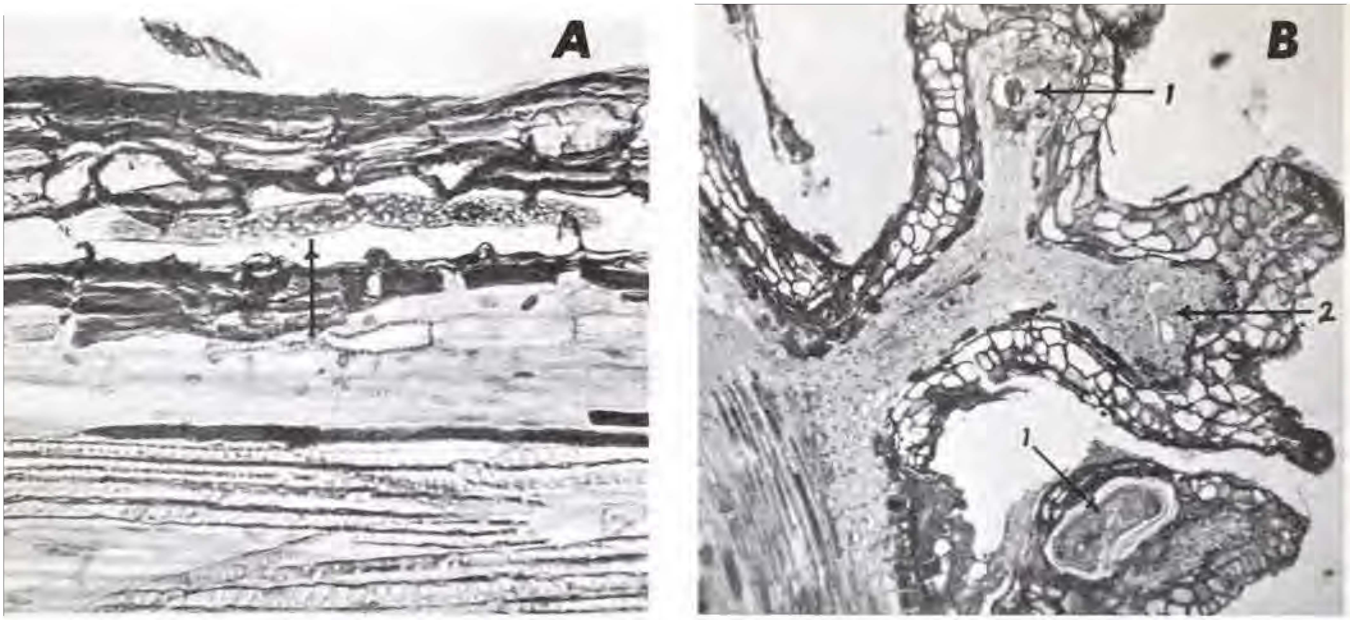


Figure 50.—Lance nematode (A) and pine cystoid nematode (B) invading pine roots. In (B), number 1 indicates female nematodes; number 2 is a giant cell.

Oak Wilt and Oak Decline

Studies on oak wilt control measures are beginning to indicate a favorable trend in the fight against this threat to our oak forests. The incidence of the disease has been consistently lower in the areas where control measures are carried out than in adjacent areas where no control has been attempted. There has been a reduction in the number of active oak wilt centers for the past 2 years in Greene County, Tennessee, where control measures are handled by the Tennessee Division of Forestry. No control measures have been attempted in neighboring Washington County, and in this case erratic but persistent increases in disease incidence have been occurring (fig 51).

The establishment and examination of oak wilt control appraisal plots is being continued. This plot system, in effect in six states, offers what is probably the best and most critical evaluaton of oak wilt control measures devised to date. Ninety-four 3-acre study plots have been established in Tennessee and North Carolina during the past 3 years as a part of this appraisal program. Preliminary results are encouraging in that they show a reduction in subsequent spread of the disease from the plots in treated areas in comparison with plots in areas where no treatments have been made. It should be emphasized, however, that these data are inconclusive and several years of critical observations will be necessary before the effects of control operations can be evaluated.

The Division has continued observations on plots established in 1958 to study oak decline, a condition that has caused extensive oak mortality from New York to northern Georgia. Apparently, several factors are involved in bringing about this injury to oaks, including drought, root fungi, and insects. Data from plot areas, as well as observations from other regions, indicate that the decline of the oaks has been arrested, since no trees in these areas have shown active symptoms since the plots were established.

In all, it has been a year in which new challenges have arisen, as well as one in which significant progress has been made, from a better understanding of how some diseases work to improved control for others.

Nineteen publications were written by the Division's personnel during the past year, covering a wide range of diseases important to forest industries in the Southeast. Perhaps most important are new ideas and research concepts providing new weapons for the attack on diseases.

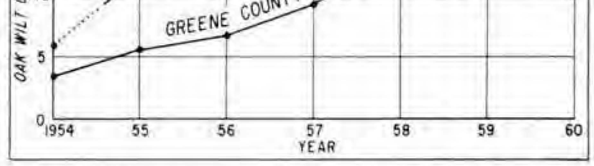


Figure 51.—Comparison of number of active oak wilt centers per 100 square miles in Greene and Washington Counties, Tennessee, 1954-1960. Control treatments applied in the former; none in latter. Dashed line indicates no surveys made.

FOREST INSECTS

Studies on the biology and control of insects destructive to flowers, seeds, and cones of pine have progressed exceedingly well. The concentrated research on this project is paying off. The collection and identification of insect species attacking host material have largely been completed. A number of important species, some of them never before collected, have been determined. Rapid progress is being made in studies of the life history, habits, and control of these species. Effective chemical formulations have been developed and, though in need of further study, may be used in practical application. With the improved facilities at the Olustee laboratory, even more significant progress may be expected.

Insects Destructive to Flowers, Cones, and Seeds of Pine

The protection of pine seed continues to take on greater importance with the increasing need for quality and quantity of seed in planting programs.

The completion of the new office-laboratory building at the Lake City Research Center has provided a stimulus to seed protection research. Entomologists now have three offices, an insect-rearing laboratory, and an insecticide-testing laboratory. The insect-rearing laboratory is equipped with constant temperature cabinets to supply a continuous population of insects for the study of life history and control (fig. 52).

In 1960 we completed collections of slash and longleaf pine material needed to determine the kinds of insects which injure flowers, cones, and seeds. Four groups of insects were commonly found:

1. Three species of *Dioryctria* that feed in cones, cankers, vegetative buds, and shoots (fig. 53)
2. Several species of *Laspeyresia* which feed only on seed of second-year cones
3. A species of thrips which injures flowers, causing them to shrivel and die
4. Itonididae maggots or flies which feed between the cone scales, causing the entire cone to shrivel and die.

A 2-year field study, designed to evaluate the effectiveness of different spray schedules of a 0.5-percent BHC water emulsion in the control of *Dioryctria* coneworms and *Laspeyresia* seedworms, was completed in 1960. The study involved three spray schedules (fig. 54). Spray schedule "A" was timed to periods in the development of the *Dioryctria* spp. when it was considered that these insects would be most vulnerable. Spray schedule "B" was based on arbitrarily selected spray dates with applications made at bimonthly intervals. Spray schedule "C" for *Laspeyresia* spp. control consisted of sprays timed with the emergence and oviposition periods of *L. ingens* and *L. anaranjada*. The two spray schedules aimed at *Dioryctria* provided highly significant control; the third schedule, aimed at *Laspeyresia*, was unsatisfactory. Exploratory studies with Guthion indicate considerable promise against both species.

Until recently, most foresters attributed the frequent death of slash pine strobili to frost. In 1960, entomologists found that thrips caused the damage (fig. 55). Tests with various insecticides indicated that heptachlor was a promising control for *Gnophothrips piniphilus* Cwfd. Studies with pathologists suggest that an insecticide-fungicide treatment may be developed to control both thrips and cone rust.

Figure 52.—Coneworms are reared in temperature control cabinets. (Here moisture is added to rearing container to provide suitable conditions for developing larvae.)

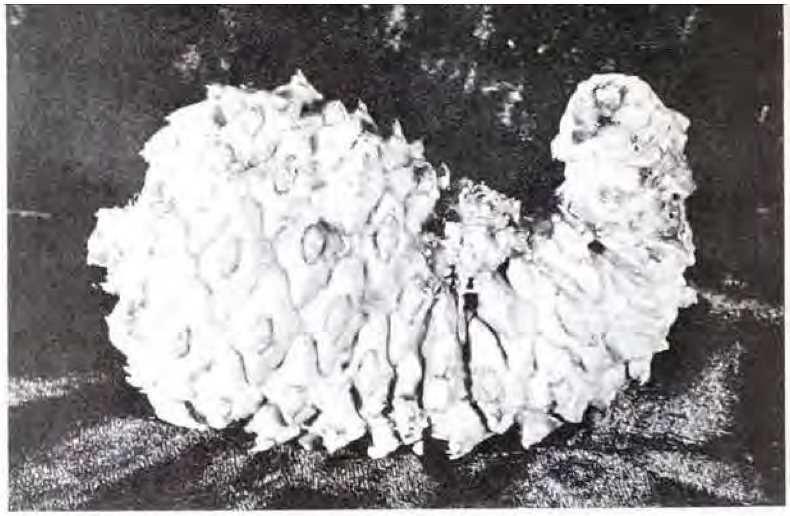


Figure 53.—When a cone is damaged by Dioryctria amatella the development of the cone and seed is arrested. Note frass in crook of cone and resin at tip.

Figure 54.—Observations are made of insect activity in field cages to determine spray schedules.

Figure 55.—Three flowers of this pine terminal were killed by thrips.

Elm Spanworm

The area of elm spanworm, *Ennomos subsignarius* (fig. 56), defoliation in the southern Appalachians has increased annually from a few scattered patches in 1954 in Fannin, Murray, and Gilmer Counties, Georgia, to over 1¾ million acres in 1960 (fig. 57).

During the last 2 years the intensity of defoliation has greatly diminished in older areas of infestation and increased in new areas to the east and northeast of the original area. Unfortunately, before defoliation diminished in areas defoliated in 1955 to 1958, millions of board feet of timber were weakened and killed, management plans were disrupted, fire danger was increased by the standing dead snags, and aesthetic, recreation, and wildlife values impaired.

Each year since 1955 aerial observers from the Station have flown 20 to 30 hours to map the intensity of feeding and areas of defoliation. These maps have been useful in keeping landowners informed about status of infestation, control needs, and various types of planning.

Figure 56.—Adults, larva, cocoons, and eggs of the elm spanworm.

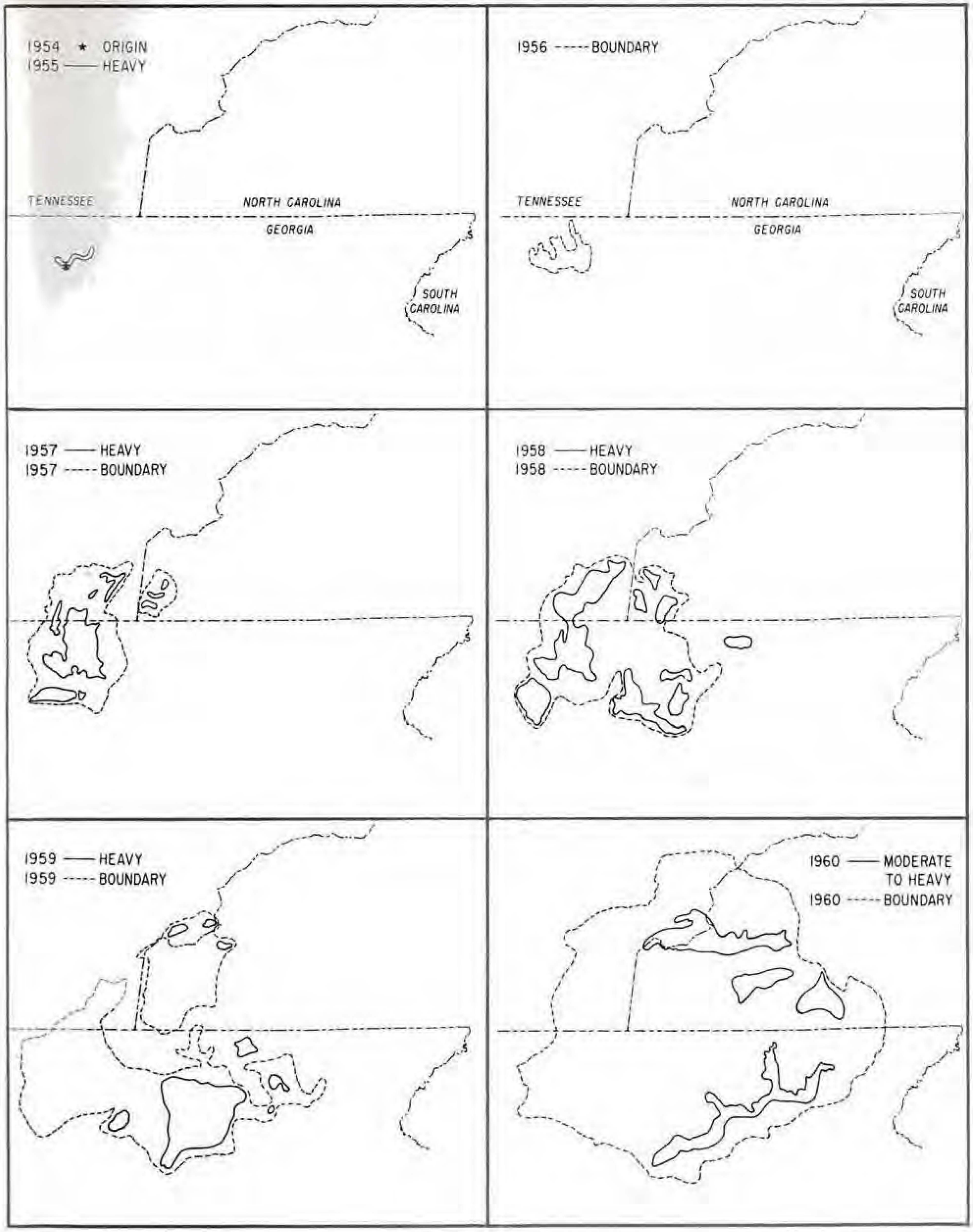


Figure 57.—Series of maps showing the areas defoliated yearly from 1954 to date.

Figure 58.—Egg mass surveys are conducted during the fall and winter by counting masses on branches collected from trees with a pole pruner. Predictions of defoliation are based on this information.

These aerial surveys and maps also made it possible to direct ground crews, at a great saving of time and money, into infested areas for egg sampling. Through egg sample surveys during the winter months (fig. 58) it has been possible to predict the probability of spanworm defoliation the following spring and the need for control planning. The aerial and ground surveys thus combine to provide lead time for management agencies to make control preparations should they be necessary.

Parasites, predators, biological control agents, and insecticides have been studied to determine their effectiveness in controlling the spanworm. At least two virus organisms that attack the larvae have been isolated, as well as over 10 parasites which kill up to 50 percent of the larvae. While these organisms have been helpful in controlling the infestation, so have late spring frosts that killed the early hatched larvae. When natural control is ineffective, particularly on high-value areas, such as recreation areas, it is possible to protect these areas through the use of either ground or aerial sprays.

Balsam Woolly Aphid

The balsam woolly aphid, *Chermes piceae* (Ratz.), has caused the rapid killing of thousands of Fraser fir during the past 3 years in the Mt. Mitchell area of North Carolina (fig. 59). The remainder of the fir stand is seriously threatened. Direct methods of control under forest conditions are impractical; therefore, a study of biological control was begun in 1959. Six species of predators from Europe and Australia have been released in the past 2 years in stands infested by the aphid.

Predators collected in foreign countries have been made available through the cooperation of the Agricultural Research Service of the U. S. Department of Agriculture, the Commonwealth Institute of Biological Control, and the Research Branch of the Canada Department of Agriculture. They are shipped to the Entomology Research Institute for Biological Control in Belleville, Ontario. Here they are carefully checked for survival and undesirable, associated species are eliminated. The shipments are subdivided, packed in special containers, and air expressed to designated areas in the United States and Canada for use in research and control of the balsam woolly aphid.

Upon arrival in Asheville, North Carolina, the insects are taken to the Entomology Laboratory and stored under refrigeration. Insects in the adult stage are ready for immediate release; those in immature stages are reared to the adult stage (fig. 60). While rearing insects, it is again necessary to screen out parasites of the immature predators. Careful handling assures a predator population free of its natural enemies.

The total number of adult predators available for release was subdivided in Asheville and placed in individual containers. These were placed in a portable ice chest and transported to Mt. Mitchell where some were released in cages placed around trees infested with the aphid to facilitate study (fig. 61). Others were free-released in infested stands. Noticeable reduction of the aphid population occurred on some release trees. It is too early, however, to determine the success of the predator introductions.

Aerial Survey Methods

In recent years considerable attention has been devoted to the development of techniques to describe forest insect outbreaks, observed from the air, with a high degree of accuracy. The objective of this research is to devise efficient means whereby significant damage levels can be recorded as they occur on the ground.

For defoliators, a series of defoliation categories are used, such as light, medium, or heavy defoliation. Differences in color help distinguish these classes, and if observed through specially designed color filters that intensify varying shades, they

Figure 59.—Entomologists checking the balsam woolly aphid on a heavily infested Fraser fir. Note the white wax "wool" of the aphid.

are readily distinguishable. Bark beetle damage is generally classified according to the number of red-topped or fading trees in a group observed from aircraft.

Personnel of the Forest Insect Laboratory at Beltsville, Maryland, have systematized the equipment and methodology for this research in cooperation with forest entomologists at the Experiment Stations around the country. In turn, the Stations have given assistance to forestry units in the States in practical application of techniques. Within the past few years both Florida and South Carolina have been advised in the use of equipment and methods for their forest insect survey programs by the Southeastern Station's entomologists.

A typical airplane survey system for level or rolling topography may be likened to the ordinary ground strip cruise. A base field map is prepared, including the boundaries of an infestation which are obtained through prior ground or aerial reconnaissance or through knowledge of the limits of the host type. The map is generally prepared from county maps with a scale of one inch equals two miles, cut and fitted together. Flight lines (strips to be cruised) are drawn at intervals, depending upon the intensity of the survey. Check points which can be observed easily from the air are lettered alphabetically along a flight line. These aid in keeping the plane on the flight line. Later, in the office, they serve as known locations for calculations of distance. With the flight lines numbered and the check points lettered, the large map is cut into two flight line strips and each is mounted on a 2-roller scroll device (fig. 62).

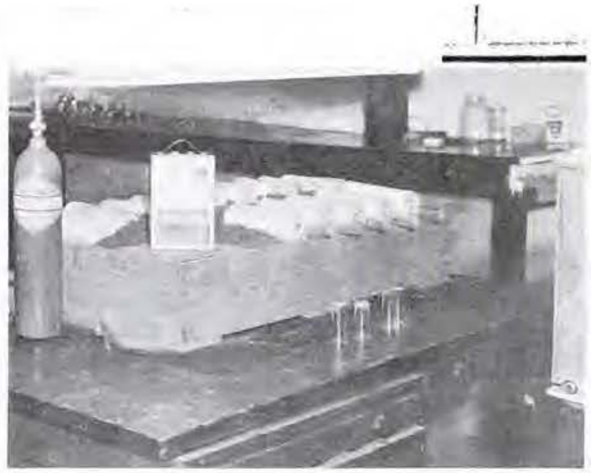


Figure 60.—Predators received in immature stages are reared to the adult stage at the Entomology Laboratory at Bent Creek.

Figure 61.—Some predators were released in cages and their life history and behavior was observed.

The next phase of preparation is concerned with recording equipment for use along the flight line. A device called an operation recorder is the central instrument (fig. 63). In response to the activation of one or more on-off switches mounted in a keyboard, pen arms trace desired data on a moving chart. Each switch is coded to represent a damage level, forest type, or whatever information is desired.

The aerial survey crew is composed of the pilot, a tracker who helps the pilot keep on the flight line and ticks off the check points with a switch on the keyboard of the operation recorder, and two observers. Each observer transmits his observations to the recorder by manipulating switches on his keyboard. These men may wear color filter glasses that aid in distinguishing different damage levels. Each uses a strip viewer, mounted on the side window of the plane, that restricts his view and maintains a standard strip width for observation.

At the completion of the flying phase of the survey, ground checks of some of the aerial observations are necessary to determine the accuracy of the survey for detail. Next, the data must be transferred to data sheets from the operation-recorder chart between each check point, flight line by flight line. This is done with proportional dividers (fig. 64). The proportion of the length of the pen line on the chart as compared with the map distance covered provides statistics on the acreages per damage level, forest type, etc. These figures may then be used as the basis for the final report.

Figure 62.—Equipment used in aerial survey. Forest insect survey team view conditions through filter glasses and strip viewers, then activate the pens of the operation recorder with the toggle switches on the keyboard. Tracker uses checkpoint indicator to keep survey plane on course.

Presently our entomologists are cooperating with the Beltsville Forest Insect Laboratory in work that takes advantage of recent advances in color photography. High-speed aerial cameras and fast color films lend themselves well to survey systems. A good photograph file would permit on-the-ground comparison of specific forest areas at any time interval desired. Resurvey photographs could be checked with the originals to learn what changes took place during the interim.

Figure 63.—Crew member places operation recorder in airplane. Survey information is recorded on the moving chart motivated by this instrument. The chart is removed later to transfer the coded information to the data sheet.

Figure 64.—Information from operation recorder chart under man's hands is transferred to data sheet at upper left. Flight line information is further processed with a calculator to provide area-wide conditions.

WATERSHED MANAGEMENT

During the year, procedures for measuring soil moisture loss reliably and with precision were further tested and improved; the effective depth of water withdrawal by tree roots for the first time was brought under systematic scrutiny and measurement; new evidence that slow drainage can be a significant component of soil moisture depletion was obtained in field and laboratory studies; the dynamics of soil moisture storage and movement on steeply-sloping small watersheds was further explored using an improved and enlarged soil model; and good progress was made in studying solar energy relations, as well as in mechanizing hydrologic data processing.

Notable progress was made in improving facilities at the Station's centralized soils laboratory at the Union field headquarters. Headed by Louis Metz and served by Soil Scientist Carroll Wells and several technicians, this unit now has facilities for complete physical and chemical analyses (fig. 65). It is handling work for all Station units, Virginia to Florida.

Most visitor interest at Coweeta continues to center on forest cutting experiments and the measured changes in water yield as determined for specific catchment units. Results of some of the earlier cutting treatments showing exceptionally large increases in streamflow yield have been widely publicized, but those from some later treatments are less spectacular and have been little reported. Although somewhat fragmentary, these later findings add much to the Coweeta record, and are reviewed briefly here.

FOREST CUTTING PRODUCES VARIABLE WATER YIELDS

The notion that forests sustain water supplies goes back to antiquity, with many contradictory claims pro and con. Forests are known to be heavy users of water, but most people still believe that deforestation will make streams dry up whereas tree planting increases low flow of streams and will make springs and wells flow again. We know now from Coweeta's controlled experiments that this frequently is not the case and as we learn more about watershed processes we can better interpret the evidence — mostly circumstantial and subjective — from reported events of this kind.

Some Russian scientists are among the latest proponents of the idea that trees when substituted for other cover will increase groundwater and hence stream yield. (Note here that efficiency of forest cover in promoting water intake and reducing overland flow is not in question.) In an International Symposium in Germany in 1959, where Coweeta results were presented in a formal paper, some five papers by Russian hydrologists reported increased runoff from forested catchments. The evidence as presented suggests snow storage effects or possibly failure to identify certain components of the water cycle; but these and indeed all findings to date illustrate eloquently some of the pitfalls in attempting to overgeneralize about such relationships or predict effects of forest cutting.

Others in western Europe are joining in the argument. In England, Penman has used physical theory to support the premise that forests use no more water than other kinds of complete plant cover. However, Law in 1956 pointed to quite different results when he reported evidence from lysimeter studies that spruce forests may use about 11 inches more water annually than a grass sward. This possibility created so much public clamor that it is threatening reforestation plans of the Forestry Commission and has prompted a vigorous research attack on the problem in Britain.

Although there are peculiar climatic situations, notably in Hawaii and Japan, where afforestation has clearly increased water supply, we can reasonably deduce that such results are rather unlikely within much of the world's temperate zones. Indeed, such evidence as there is — scattered and incomplete for the most part — suggests contra-results and probable increases in water yield after clear cutting on the order of 3 to 6 inches (neglecting Coweeta experience).

Effects of Cutting at Coweeta

Coweeta, as the first research unit to experimentally demonstrate some of these relationships, is a natural focal point of world interest in this controversy; and it remains the most prolific single source of data from carefully-controlled watershed experiments demonstrating that forest cutting in humid country can sometimes increase water yield substantially. Altogether, 12 watershed treatments involving forest cutting of some kind have been made at Coweeta in the past 20 years. Some of the findings are new — several treatments have only recently begun to produce

Figure 65.—Soils analyses at the Union Laboratory greatly aid forest research.

results — and some are old and widely known; but all are from precisely-gaged small watershed units on which mountain hardwood stands have been altered by varied levels of cutting and subsequent changes in evapotranspiration loss measured through long-term records of precipitation and streamflow.

Obviously, the Coweeta catchments, as elsewhere, cannot be regarded as similar in all respects except treatment since each has its own peculiar geology, aspect, soil mantle, and climatic regimen affecting hydrologic performance. Accordingly, we have minimized these difficulties by employing a control watershed with each treatment, and assessing changes in water yield through the changed relationship between treated and control units.

Coweeta's findings as to water-yield increase have been quite variable but show a direct and consistent relationship to severity of cutting as well as watershed aspect. Table 6 shows first-year increases in water yield from nine cutting treatments; and figure 66 shows the increases graphically in relation to the mean-annual flow prior to cutting. These increases came as regulated base flows and with no measurable changes in peak discharge or turbidity, since, as before treatment, less than 10 percent of total yield was storm discharge and none of this reached streams as overland flow. Prior to cutting, each watershed and its control supported dense, second-growth hardwood stands averaging 100 to 120 square feet basal area per acre.

As widely reported in many publications, two of the early Coweeta treatments, on predominantly north-facing Watersheds 13 and 17, produced very large first-year increases in yield—15 and 17 area inches of streamflow, respectively—after all woody vegetation had been clear cut and lopped. More recently, these findings were reinforced by a proportional increase in yield (8

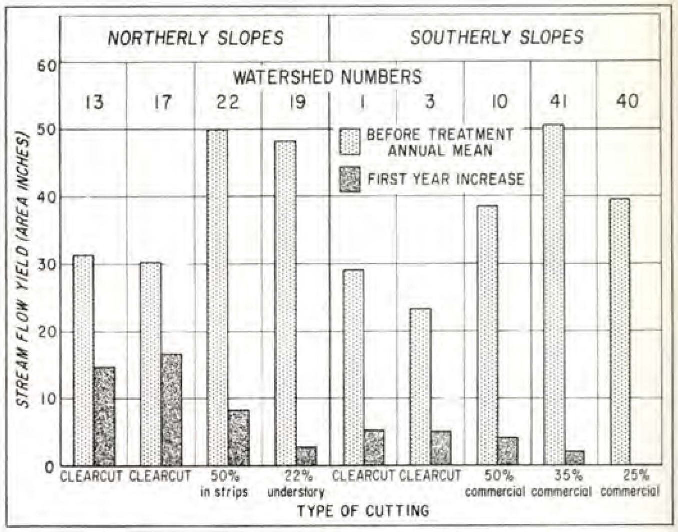


Figure 66.—Streamflow from watersheds of north and south aspect before and after cutting.

Table 6.—Increases in water yield from forest cuttings on north and south slopes

Watershed		Treatment	Basal area removed	First year streamflow increases
NORTHERLY ASPECT				
			Percent	Inches
13	(40 acres)	Woody vegetation felled and lopped	100	14.7
17	(33 acres)	Woody vegetation felled and lopped	100	16.8
22	(85 acres)	Woody vegetation poisoned on 33-foot strips	50	8.1
19	(70 acres)	Understory cut and lopped	22	2.8
SOUTHERLY ASPECT				
1	(40 acres)	Woody vegetation felled and lopped	100	5.1
3	(23 acres)	Cleared for mountain farming	100	1/ 5.0
10	(212 acres)	Commercial timber sale, no restrictions	50	1/ 4.0
41	(71 acres)	Commercial timber sale with safe logging	35	1/ 2.0
40	(50 acres)	Commercial timber sale with safe logging	25	1/ 0.0

1/ Approximate values from weakly controlled, demonstration-type experiments.

inches) obtained from Watershed 22 the first year after half the basal area on alternate 33-foot strips had been chemically poisoned (fig. 67). Moreover, in an early experiment about 3 inches increased flow was obtained from Watershed 19 when all the rhododendron-laurel understory, accounting for about one-fifth of total woody basal area, was cut and lopped.

These findings led us to think until quite recently that large increases in streamflow, proportional to the reduction in basal area, would be the rule rather than the exception when cutting Coweeta's well-watered timber stands. But quite different results were obtained when Watershed 1 — one of the better controlled south-facing units — was clear cut in 1954. In an initial treatment in which all trees and shrubs in the cove site were cut or deadened, thus eliminating 25 percent of basal area on the entire drainage, there was only a 2-inch increase in streamflow the first year — much less than expected. Then, subsequent cutting of all material on the rest of the 40-acre catchment yielded only a 5-inch increase the first year, or about one-third that obtained on north-facing Watersheds 13 and 17. Moreover, despite repeated annual cutbacks of sprout growth, the measured increase by last year had dwindled to 1.8 inches.

Just why such radical cutting treatment paid off so poorly on Watershed 1 is by no means clear. Prior to cutting, the indicated loss of water through evapotranspiration (precipitation minus runoff) for north- and south-facing forested units did not differ appreciably. Nevertheless, it seems evident that when we apply similar cutting treatment to south-facing watersheds we will accomplish far less in the way of reducing net loss of water to the atmosphere and hence can capture a smaller residual as streamflow.

Note that results for other south-facing watersheds help document this conclusion (table 6 and fig. 66), although it should be added that these

Figure 67.—Coweeta Watershed 22 where half the basal area was eliminated by poisoning alternate strips. View taken after one of the rare snow storms. The cleared unit in the left background is Watershed 17.

estimates are adjusted approximations from demonstration-type cutting experiments and include some indeterminant amounts of error. Hence it appears that heavier cuts will be needed on south-facing watersheds to produce increases in water yield equivalent to those obtained on opposite-facing units. These data suggest that the ratio *inches increase/percent reduction in basal area* for south-facing units is about half that for the north-facing units.

Other Factors Affect Water Yield

Such findings serve as a useful warning that a watershed experiment, no matter how precisely controlled as a unit, represents only a single observation on effect of treatment; and that each catchment has its own unique attributes, not limited to watershed cover and related factors, which can strongly affect the water disposal processes and hence water yield. As shown, aspect exerts strong influence, but soil structure, depth, distribution, and other physical factors are doubtless also influential.

To check out one logical factor, we have calculated the total solar energy available to opposing Watersheds 1 and 17. Although summer radiation is quite similar in total amount, the south slope lies at an angle to receive almost twice the radiation of the north slope in the dormant season (figures 68 and 69). Quite possibly, therefore, greater evaporation loss from Watershed 1 during the winter months accounts in part for our failure to get much dormant season increase in flow after cutting. If this is so, it is still not clear why both watersheds apparently lost about the same quantity of water to the atmosphere when in high forest and before they were cut over.

Another potent factor may be the variable storage afforded by experimental catchments. There are real indications of differences in storage depletion relationships and hence yield among the various Coweeta watersheds; for example, Watershed 1 always has had better sustained base flow than most of the catchments. Although we have not been able to relate changes in yield after cutting to storage attributes or other definable physical features of the units, it is a reasonable premise that such characteristics as shape, mass, and location of the main storage aquifers with respect to stream channels may account for some large differences in response of streamflow to treatment.

What then have we learned at Coweeta about altering water yield by forest cutting other than that there are no simple answers? For one thing, we have demonstrated conclusively that conversion from well-watered high forest to low vegetation can increase base flow of streams appreciably; and that we can produce variable first-year increases in water yield on the order of 3 to 16 inches by clear cutting mature stands. These increases are likely to be smaller, on an average, than we used to think; but they are nonetheless real, and fortunately for management purposes tend to occur during drier seasons when water supplies are scantiest. The indications are that the payoff in water yield will vary roughly with percent reduction in basal area; and although the yield increases will decline with time as trees grow back, they may in some instances persist many years after certain stands have been heavily cut over. Beyond this, Coweeta experience suggests that aspect and related climatic variables, soil storage relations, and other physical factors strongly influence the level of increase we can expect from forest cutting. The results to date indicate that a prescribed basal area cut on a southern slope will yield proportional first-year increases in water yield about half those to be expected from northern slopes.

It should be remembered that forest cutting, as is true of other treatments, creates an environment that begins to change biologically almost before cutting activities are completed, and it is doubtful whether such treatment can ever be considered independently of the piece of land receiving it. Because it usually will be too costly and inefficient to seek answers by replicating expensive unit-watershed treatments, we must learn through study of processes how a watershed unit produces water and which factors are important variables affecting water yield. Some parts of the puzzle are known and the new work at Coweeta is pointing up others. But all the major variables will have to be identified and carefully studied as to order of logical influence on water yields before reliable predictions of forest cutting response can be made for the southern Appalachians or other key water-yielding areas.

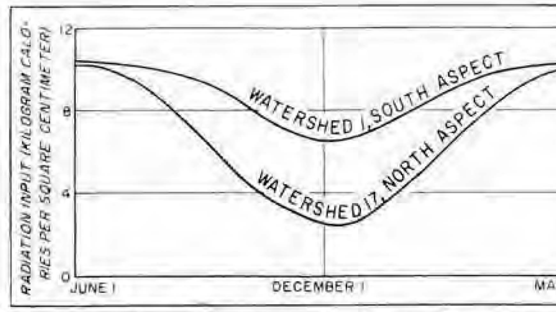


Figure 68.—Comparison of solar radiation theoretically available on watersheds of north and south aspects.

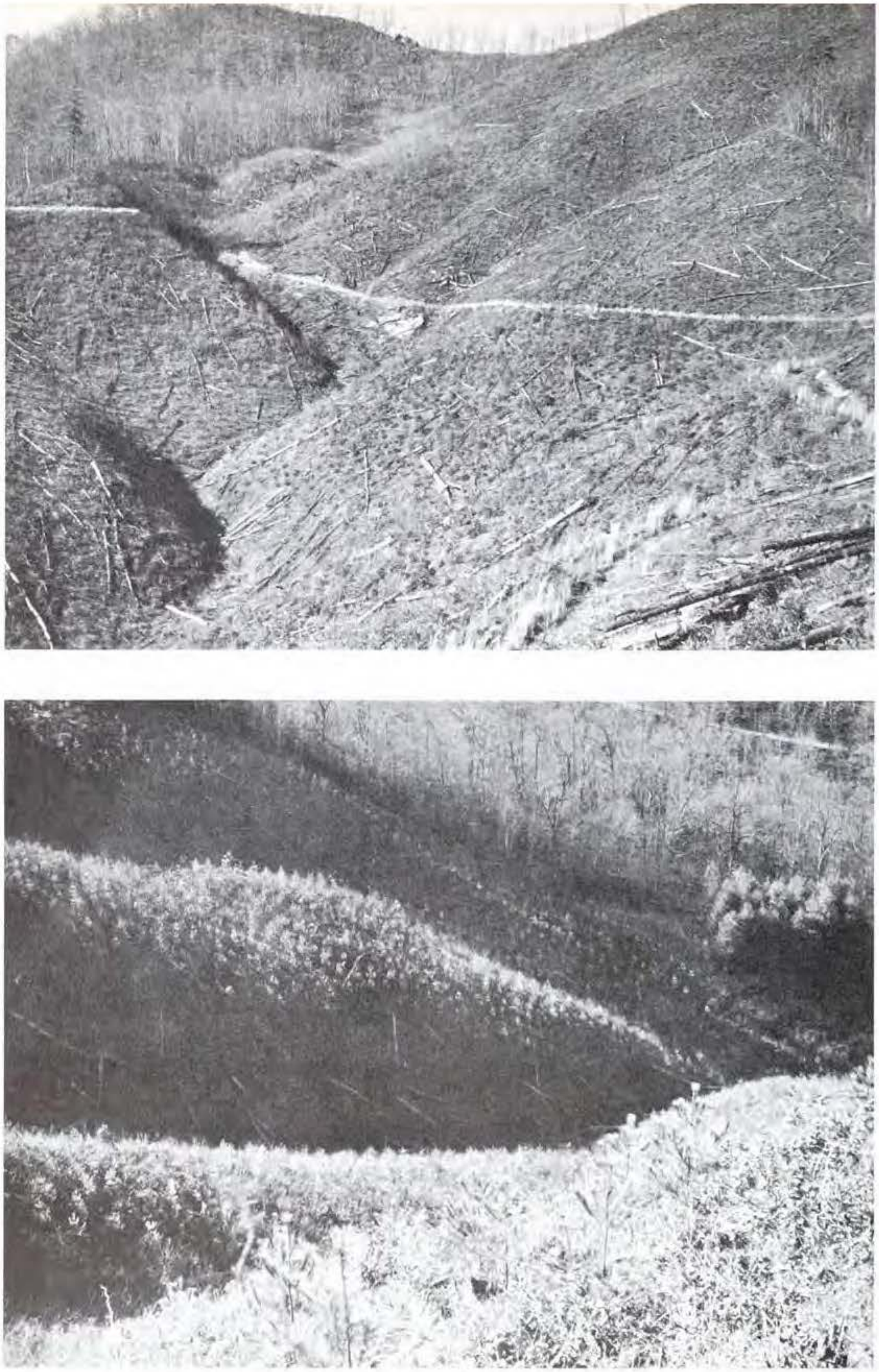


Figure 69.—Comparative sunlight received during the dormant season by Watershed 1, (above), and Watershed 17, (below). Both photos taken about 2:00 p.m. in mid-December at right angles to the sun and in a northwesterly direction.

RANGE, WILDLIFE HABITAT, AND FOREST RECREATION

RANGE

Range research at Tifton, Georgia, and Fort Myers, Florida, continued to emphasize ways and means of producing cattle and timber on the same land. An important phase of the work is control of sawpalmetto and gallberry. Both species compete aggressively with other plants and pose problems in managing young pines and native forage. Although both species afford wildlife benefits, it is probable that reduced quantities will still satisfy game needs. Consequently, considerable effort at Fort Myers and Tifton is being directed toward rounding out our knowledge of these plants.

Sawpalmetto

Sawpalmetto, *Serenoa repens,* a dominant shrub in the Florida flatwoods, is an important component of the shrub layer throughout the coastal plain forests from South Carolina to Louisiana (fig. 70). Throughout most of its range, sawpalmetto is considered an economic liability by cattlemen and timber growers, but their attempts to eradicate it have met with indifferent success.

And yet, surprisingly little data have accumulated on its life history, so little that effective control has been hindered by lack of knowledge. Hence, the autecology of sawpalmetto is being studied intensively with respect to distribution, seed germination, factors affecting establishment and early growth of seedlings, phenology and growth of mature plants, and the structure and dynamics of the palmetto community.

Burning is commonly employed by south Florida ranchers as a tool to reduce palmetto coverage and encourage resprouting of nutritious range plants. The effects are short-lived, however, as palmetto resprouts vigorously after burning and is apparently a fire subclimax species where ranges are burned no more frequently than once in 2 years during the winter season (fig. 71). Except for this brief period after burning, palmetto is seldom eaten by cattle.

Although, separately, burning and grazing appear to be ineffective control measures, some combination of the two may be useful in controlling or reducing palmetto dominance. In October 1956, wildfire burned approximately two acres of a 90-acre experimental unit on the Caloosa Range. This area, unburned except for the 2 acres, was stocked at a high rate, allowing 15 acres per animal unit per year. Heavy grazing for 2 months following the wildfire virtually eliminated the palmetto. Grazing during subsequent periods when cattle were on this range further removed the sprouts, and the general aspect changed from sawpalmetto dominance to broomsedge-sedge dominance (fig. 72). Once the palmettoes are killed in this manner, stocking should be adjusted to facilitate maintenance of desirable forage species.

Figure 70.—Sawpalmetto is the dominant shrub on many flatwoods forest rangelands.

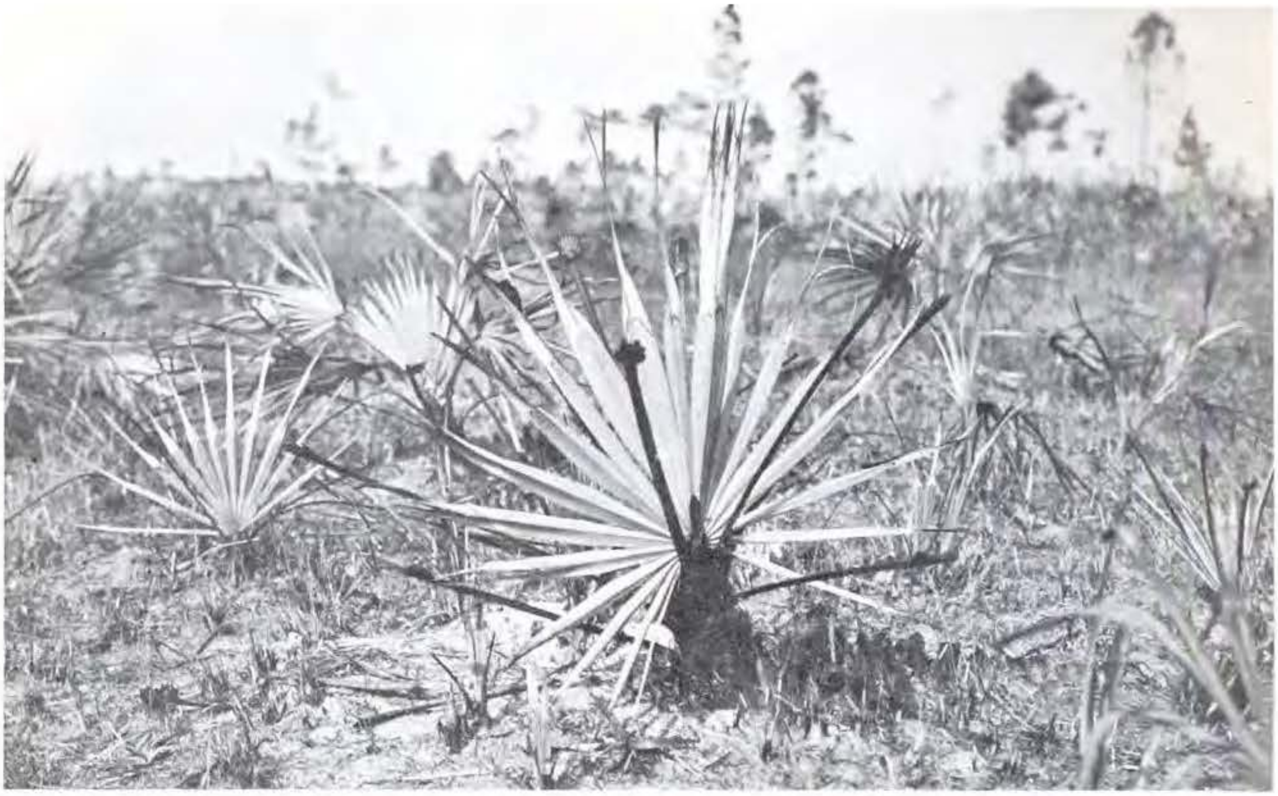


Figure 71.—Sawpalmetto produces vigorous new fronds after burning.

Figure 72.—Range aspect changed from sawpalmetto dominance (left) to broomsedge-sedge dominance (right) following October burn and heavy grazing.

Gallberry

Gallberry (fig. 73) is the most abundant of some 20 native and introduced members of the holly family. Because of its stoloniferous habit, it often grows in dense thickets, some of which may be over 100 years old. Seedlings of gallberry are rare, and virtually all new growth originates from sprouts (fig. 74), although large numbers of seed are produced from pistillate plants every year. Apparently, few gallberry seed or germinating seedlings escape depredations by birds, rodents, insects, fungi, and other agents. Birds eat both fruit and pulp of gallberry during the winter but apparently few viable seeds pass.

Sprouts from plants retarded by test fires on the Alapaha Range in January 1956 were checked at weekly intervals the next 2 years. Growth of sprouts in 1956 and twigs in 1957 started in late February, and the period of most rapid development was April 15 to May 15. Growth of older stems stopped in late October and sprouts in November. Average growth of basal sprouts in one year was 21 inches and terminal twigs 9 inches.

New leaves, which began appearing in late February, reached half size in April and full size in May. Sprout leaves were slightly larger than leaves on the older stems after June. Leaf shedding from older plants began in September and continued gradually throughout winter and spring with leaf-fall completed in May. Sprouts held a portion of their leaves into the second summer.

The rudimentary flower buds appear mainly in March and in about a month attain full size. Flowering was observed to be completed in May, with young fruits on the pistillate plants reaching half size by June 1, and ripening gradually during the summer. The berry-like drupes turned black in August, and remained on the plant until the following spring but began falling when new growth started. Final shedding of fruit occurred in May. The ripened fruit on plants that were observed averaged one-fourth inch in diameter and contained 2 to 9, usually 6, flattened nutlets. Plants killed back by fire bore neither flowers nor fruit until the second year.

Results from tests in cooperation with the Georgia Coastal Plain Experiment Station and the Agricultural Research Service, USDA, employing fire and chemicals indicate that the cost of effective control measures will remain rather high, and that further knowledge of the ecology and growth requirements of the species can best guide future control efforts. Ultimately, a combination of chemical, mechanical, and management procedures may prove more effective than any single type of treatment.

Figure 73.—Gallberry alone or with sawpalmetto frequently dominates the understory of the coastal flatwoods, even beneath a full stocking of pine.

Figure 74.—Results of test burning on the Alapaha Range in south Georgia. Seedlings of gallberry are rare and new growth originates from sprouts.

WILDLIFE HABITAT

Essentially, this program is a joint effort between the Station and the U. S. Fish and Wildlife Service, with Station research centered on habitat aspects of problems, and Fish and Wildlife Service efforts concerned with the animal biology phases.

During the year, major effort continued on several studies to appraise effects of forest management practices on game habitat. Notably, these included cooperative site preparation studies

at Lake City with the Florida and Georgia Game Divisions; appraisals of forest-wildlife management systems under leadership of the Virginia Cooperative Wildlife Research Unit on the Broad Run Area of the Jefferson National Forest; and a study of forest cutting practices in relation to deer forage production on the Pisgah National Forest in western North Carolina (fig. 75). Also, studies of overbrowsed deer range are now active, with large exclosures on the Toecane Ranger District of the Pisgah Forest. This study will document successional development of browse plants and commercial timber species after the cutting of protected and open areas of badly overbrowsed deer range (fig. 76) and will lead to experimental trials in rehabilitating these abused ranges.

Considerable effort has gone into development of methods for inventorying game and plant populations. Fish and Wildlife Service techniques for censusing deer populations using imprint counts are proving especially productive and are undergoing further study.

One of the more interesting developments involves frequency sampling of key browse species at 20 points surrounding each Forest Survey plot to obtain index values indicative of relative carrying capacity for deer in trial counties in Georgia. Frequency samples were taken in cylindrical plots defined by projecting a circular milacre upward 4½ feet. If living materials of any woody plant were found in the sampled volume, the species was tallied by an appropriate code number. Frequency data were summarized for each plot by sorting the most abundant species at each point into forage preference classes (preferred, staple, emergency, stuffing, and no browse). Preference distributions were coded and punched on cards for electronic sorting, and the values were analyzed for the main forest types.

Results from a trial sampling in Laurens County, Georgia, are highly indicative. They show that only 2 percent of sampling points in the slash pine type are dominantly in preferred browse, with staple foods dominant on 10 percent of the points, and the remaining 88 percent supporting poorer forage or no browse at all. In contrast, in the pine-hardwood and water oak-gum types 45 percent of points had staple and preferred feed and 55 percent were dominantly occupied by emergency and stuffing foods or no browse.

Other analyses illustrate significant relations between stand size and distribution of deer forage, with much higher proportions of preferred and staple food in sawtimber than in poletimber and sapling stands.

Table 7 presents index values of the distribution patterns of the preferred and staple browse classes when combined by types.

Although we could expect more quality browse in hardwood or mixed hardwood types, the mag-

Figure 75.—Studies of timber cutting and clearing practices and their effect on deer forage production and use are under way on the Pisgah National Forest.

Figure 76.—The whitetail figures in much of the habitat research because of its great capacity to modify range — often to the detriment of other resources as well as its own well being.

Table 7.—Proportion of sampling points on which preferred or staple foods are dominant

Type	Percent of sampling points	Standard error
Slash pine	12.1	2.6
Water oak-gum	45.9	5.1
Pine-hardwood	45.0	6.1

nitude of the differences are extremely interesting. For example, only 8 percent of the points sampled in hardwood types were not occupied by browsable material, in contrast with 31 percent in the pine type. Conversely, in the pine type the preferred and staple foods were dominant on only 12 percent of the points, whereas 45 percent were so characterized in the hardwood types.

These data, obtained statewide and on a recurring schedule, can be extremely useful in characterizing quality of deer range and charting trends. Although the trials have not involved sampling for browse utilization, this seems entirely feasible and would add much of value in future surveys. For one thing, it would greatly strengthen information about deer preferences and thus lead to a better interpretation of forage differences between units of deer range. Although this type of sampling does not yield quantitative estimates of available forage, it is quite likely that, with a modicum of training effort, gross weight estimates of the available forage could be obtained readily.

Despite the fact that the Forest Survey inventory was limited to deer browse, sampling for other game foods should be equally feasible, particularly for seed-bearing plants on unit plots which contribute valuable food for quail, turkey, grouse, and other game species.

FOREST RECREATION

Research relating to recreation in the forest, as such, was actively begun in midyear. As a result, we can only report on studies started and planned. A study to measure hunting pressure and kill as related to game levels is under way on the Broad Run Area of the Jefferson National Forest in cooperation with the Virginia Cooperative Wildlife Research Unit.

Data from this study suggest that hunting pressure in such newly-accessible improved areas may increase quickly and then level off (table 8). For Broad Run, the indications are that pressure has now reached a relatively stable level but may increase gradually.

Table 8.—Hunting pressure and success on the Broad Run Area, 1957-1960

Year	Total pressure	Deer kill	Success
	Man-hours	Number	Hours/deer
1957	248	7	35
1958	1,435	6	240
1959	775	6	129
1960	1,158	6	193

Planned studies are concerned directly with dispersed forms of forest recreation, including hunting, fishing, hiking, nature study, and camping not associated with developed sites. Collectively, these are important types of recreation on southern forests (fig. 77); and this is especially true of national forest lands in the mountain areas of Virginia, North Carolina, and Georgia.

Figure 77.—A hiker in the mountains of western North Carolina not far above the Georgia border. How many such hikers travel the main ridges and approach trails? Sampling models are being developed and tried to measure total dispersed recreation for large planning units of forest land.

A priority problem in managing forest lands for recreation use is that of reliably estimating total use loads and types of recreation. Accordingly, a new study is getting under way to develop methods of identifying and estimating total dispersed recreation for fairly large planning units of forest land of 50 to 100 square miles (fig. 78). This is being financed by cooperative funds provided by the Station and administered by the Virginia Cooperative Wildlife Research Unit, with joint supervision and guidance by the Southeastern Station and Unit. The sampling model, questionnaire, and interview procedures will be pilot tested for a single management unit on the George Washington National Forest. The study should produce a very large body of information about dispersed recreation use of forest lands year-round, together with a basis for predicting future use.

Also planned is an extensive case history study of some 75 to 100 developed campground-picnic areas on the Nantahala, Pisgah, and Cherokee National Forests to observe user-load impacts on native flora, forest soils, and other biological and physical aspects (fig. 79). This will help forest managers in selecting new areas for development and in rehabilitating recreation sites presently abused. This will also put the finger on the most critical problems associated with heavy recreation use on developed sites.

Figure 78.—Recognizing the user in the forest is only part of the job — knowledge of where he comes from is also a big help in predicting future demands.

Figure 79.—Knowledge of the impacts of recreational use on the physical and biological properties of a developed site is essential.

FOREST FIRE

Danger Ratings as a Guide to Air Patrol

Aircraft patrols are being used more and more in the South because of their speed and versatility. They are especially useful in checking smokes for further ground suppression action and in scouting the progress of large fires. Aircraft are also used to supplement tower detection during periods of low ground visibility and in various aspects of fire prevention and law enforcement.

A fire control manager needs guidelines to help budget flying time in order to buy the most protection for his money. Other things being equal, it can be assumed that air patrols should be made on days and during hours when the probability of fire occurrence is greatest. Past work demonstrated a good correlation between fire occurrence and measured fire danger as indicated on our 8-100-0 danger meter. As the burning index increased, the probability of fires also increased.

In the belief that danger measurements could serve as a partial guide to air patrol, an analysis was made of almost 5,000 fires that occurred in the ten districts of Georgia in 1959 during the five most difficult months, January through April, and December. Partial results, summarized in table 9, strikingly indicated that as danger increased, the number of fires also increased.

During these 5 months, some fires originated every hour of the day, but the greatest number, 71 percent of the total, originated between noon and 5 p.m. This worst 5-hour period was selected for computing purposes on the assumption that pilot and observer could patrol for that length of time without undue fatigue.

Table 9.—Number of fires, days, and fires per day by burning index ranges for 10 districts, Georgia, 1959

Burning index range	Jan., Feb., Mar., Apr., Dec.		
	Fires	Days	Fires per day
	- - - - -	Number	- - - - -
1	46	308	0.15
2-5	754	442	1.7
6-17	2773	615	4.5
20-45	1421	145	9.8
Total	4994	1510	

Table 10 summarizes major results of the analysis. For example, had air patrols been made from noon to 5 p.m. on all days having a burning index of 6 *or more*, flying would have been done on 50 percent of the days. On these days and during these hours, 60 percent of the fires in the 5-month period occurred and should theoretically have been observable under favorable visibility conditions.

Records of several years must be analyzed before a good guide based on probability of fire occurrence can be developed.

Table 10.—Relation between percent of patrol days and fires and burning index for 10 districts, Georgia, 1959

Patrol days (Percent)	Burning index	Fires
	Units	Percent
10	20	20
20	13	33
30	10	44
40	7	50
50	6	60
60	5	64
70	3	69
80	2	70
90	1	70
100	1	71

Drought Index for Organic Soil Areas

Work was completed this year on a preliminary method for predicting water table level in organic soils from weather variables. Depth to the water table is closely related to the depth or thickness of the dry flammable soil layer and, hence, to relative drought severity.

The relation of the rise in water table to precipitation for four study sites in coastal North Carolina is shown in figure 80.

Fall in water table level was most closely correlated with 2 p.m. air temperature (fig. 81). Addition of a second factor, 2 p.m. dewpoint temperature, improved correlations for some sites.

Given a starting water table level and the site information presented in figures 80 and 81, a bookkeeping system can be set up to predict depth of the water table at any time.

Work is continuing on the two additional items needed to complete a preliminary drought index: threshold moisture content for ignition of organic soils, and relative difficulty of control and mop-up of actual fires with an increasing thickness of the flammable layer.

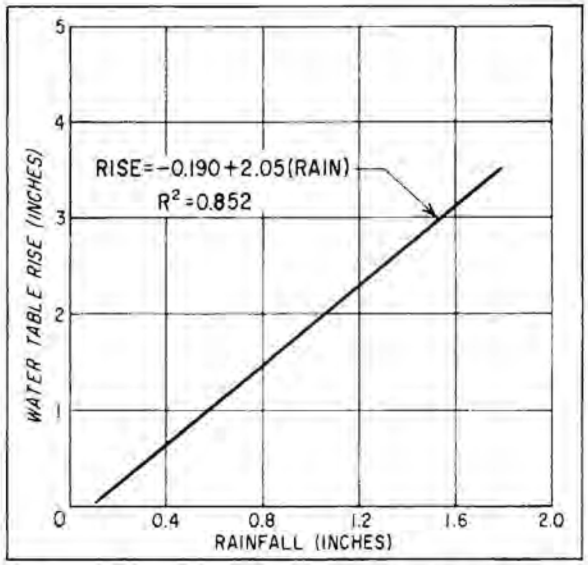


Figure 80.—Water table rise as a function of rainfall for a shallow (2 foot) woody peat soil type. The overstory is scattered 20-foot pond pines; the understory 6- to 10-foot switch cane and brush. Dare County, North Carolina.

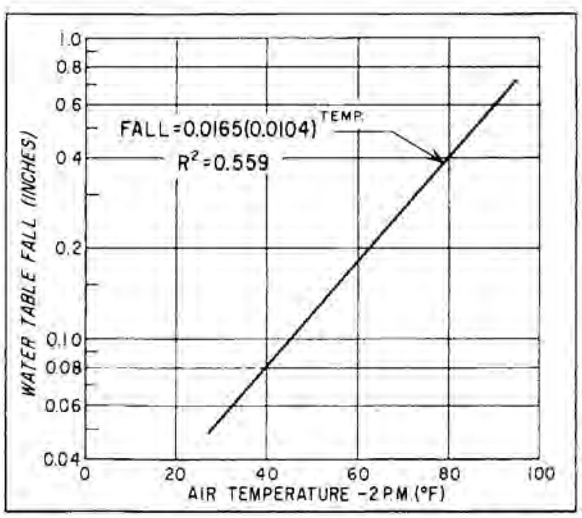


Figure 81.—Water table fall as a function of 2 p.m. air temperature for the same soil and cover type described in figure 80.

Combustion Fundamentals

Until a quantitative prediction of the persistence and spread of a fire under given conditions is possible, we cannot pretend to understand the process of fire-front propagation in a sufficiently exact way to provide much assistance in directing our efforts to the control of forest fires. An expression for the rates of combustion as a function of fineness and arrangement of the fuel, fuel geometry, fuel moisture content, and surrounding atmospheric conditions is needed if we are to understand the basic principles of ignition, fire buildup, and spread.

The possibility of similarity between various systems of even wholly unrelated fields suggests the exploration of phenomena by means of "models" of either enlarged or reduced scale, or by means of analogies from a different field. The use of models is prominent in the basic studies involving fire physics and fire chemistry.

At the Southern Forest Fire Laboratory, efforts are aimed toward:

1. Discovering how forced and free convection of air and hot gases associated with a liberation of heat interact with the burning process.
2. Measuring the radiant heat transfer due to gas and flame emission and gas absorption.
3. Examining critically the ways in which fundamental physical and chemical phenomena of fires are altered by the addition of suppressants.
4. Developing fundamental information on the aerodynamic properties of firebrands or burning embers that are associated with the spread of large fires.
5. Studying the mechanism and thermochemistry of pyrolysis and oxidation of solid combustibles, which involve heat and mass transfer coupled with endothermic and exothermic reactions within the solid phase.
6. Ascertaining the model laws for uncontrolled aerothermodynamic systems where the rate of fuel consumption is dependent on the rate of evolution of heat and on the rate of transport of oxygen to the combustion zone. A system will be designed to use experimental fire models with controlled fuel, fuel bed, fire base, and atmospheric conditions. With such experimental fire models, necessary information will be obtained on the following, as affected by the properties of the air, fuel, and base:
    a. Rate of energy released
    b. Distribution of the energy released
    c. Temperature, pressure, convection, and radiation patterns in and around the fire

d. Composition of the volatile gases immediately before ignition, and also during and after combustion
e. Flame height and volume.

Currently, efforts are concentrated on an experimental fire model utilizing the combustion laboratory facilities at the Southern Forest Fire Laboratory. With this model researchers are investigating fundamental factors which govern uncontrolled fires, evaluating the importance of significant variables, and reproducing their effects. Basically, the model consists of a specially built burning table on which cribs of wood, constructed to exacting standards, are burned. The crib is ignited at one end and the flames progressively spread to the other end, reducing the crib to a residual of charcoal and ash. As the flames spread, the crib is fed into the fire by means of a chain belt mechanism in the burning table so that the flames are maintained in a fixed position in space (fig. 82). This results in a "steady state" fire and data may be collected over an extended period of time using instruments mounted in a stationary position.

Wind Direction for Prescribed Burning

A study has been completed on the wind directions most likely to persist during a prescribed burning period. Wind roses for each month for seven Weather Bureau Stations in South Carolina, Georgia, and Florida were constructed, using 10 years of data. The results indicate that for the coastal plain of South Carolina, Georgia, and northern Florida:

1. During the winter burning season (December through March) westerly winds are more persistent than easterly winds.
2. In early autumn (September and October) northeasterly winds are most persistent, while November is a transitional month between the early autumn and winter regimes.
3. The other months are much less consistent and in many areas favorable winds are so rare that burning may be extremely difficult in the warmer months.

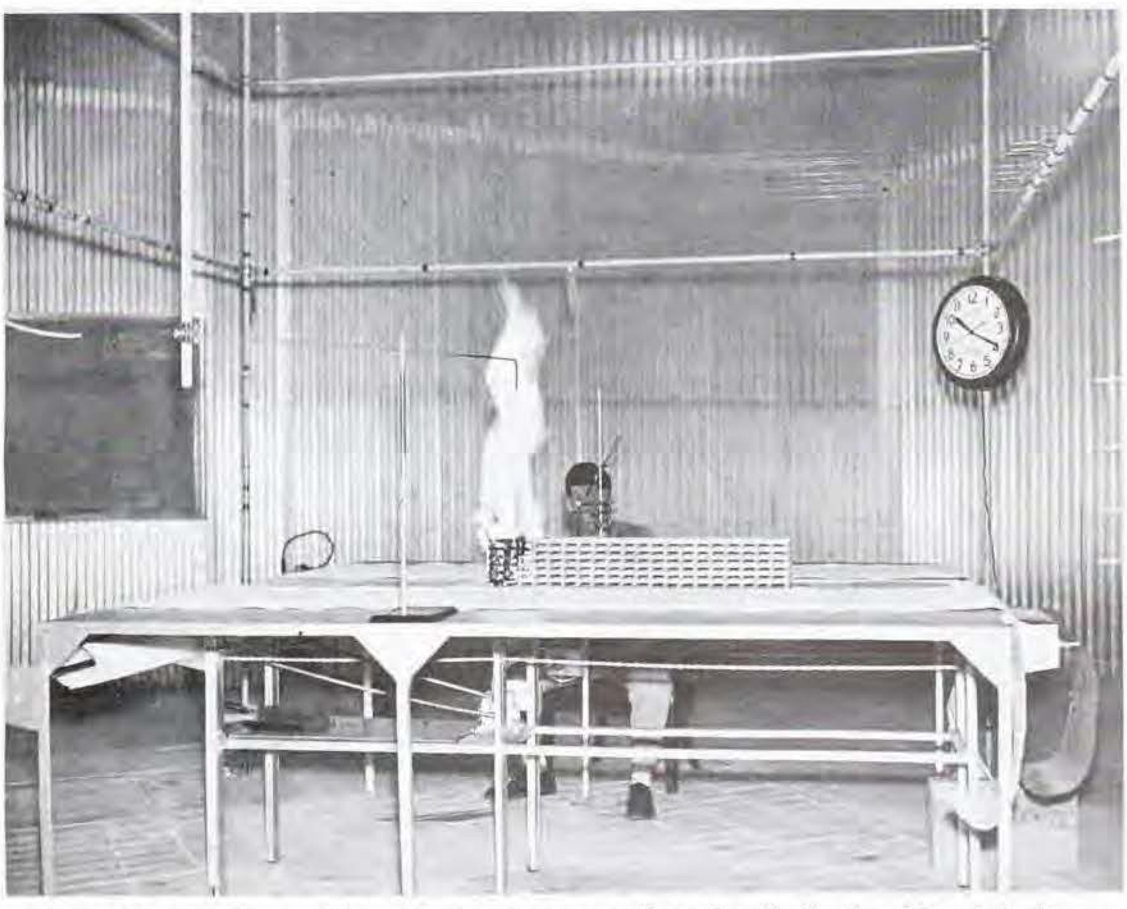


Figure 82.—A crib fire at different times during a test, illustrating the fixed position of the flame as the crib was moved.

Performance of the 8-100-0 Meter in Georgia

The first annual recapitulation of fires and acres burned in relation to measured fire danger has been completed for Georgia. Use of the 8-100-0 meter as a fire control tool proved reliable for this State. This and future analyses will indicate trends of fire danger, provide accurate basic data for fire control planning, and serve as a source of data for fire research.

In all districts and statewide it was found that number of fires, including the 15 percent incendiary fires, bears an approximately straight-line relation to numerical burning index on the 8-100-0 meter (fig. 83). In general, burning index doubles as the number of fires doubles. Acres burned per day, which is a rough measure of job load, and average size of fire, which is related to rate of spread, are closely correlated with numerical burning index throughout the State (figures 83 and 84). Correlations are improved when Class E fires (300 acres or larger) are omitted.

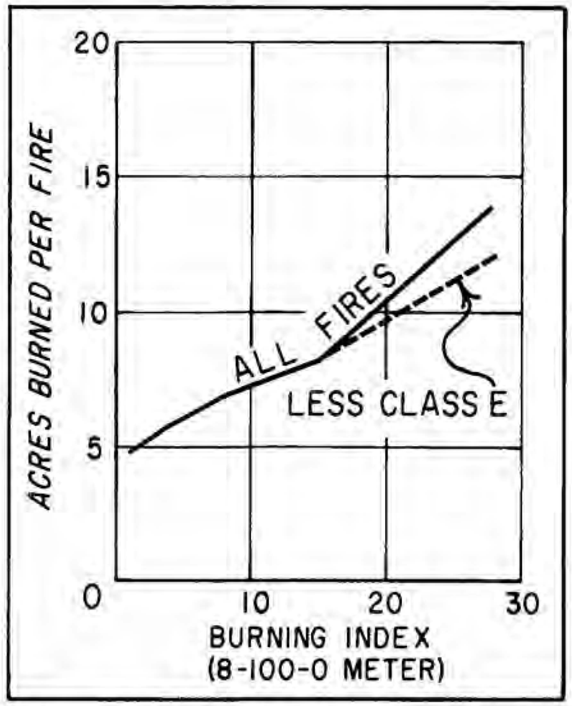


Figure 84.—Number of acres burned per fire (average size of fire) versus numerical burning index on the 8-100-0 meter. Georgia, 1959.

Fuel Studies

Results from trial prescribed burns on the Waycross State Forest in south Georgia in 1959 and 1960 indicate that backing fires consume more dead fuel than fires that run with the wind. The reverse was true for live fuel reduction. For safety reasons, initial burns in heavy fuel types must be restricted to backfiring techniques, but follow-up burns can make practical use of strip-head fires with more lasting green fuel reductions. Since vegetative regrowth (fig. 85) following a single winter backfire in palmetto-gallberry fuel types is so prolific that live fuel weights and volumes may actually exceed original values within 2 or 3 years, repeat burns need to be made before the vegetative material reaches this stage. Palmetto and gallberry regrowth is retarded most effectively when reburns are possible during the first fall season following winter backfires (fig. 86).

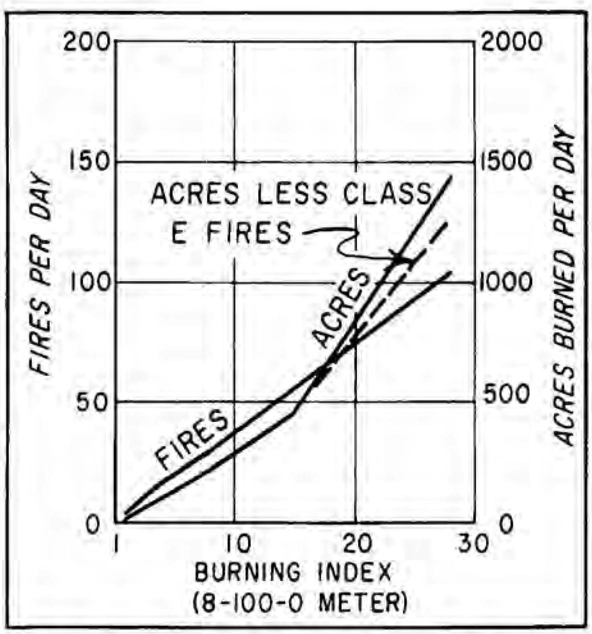
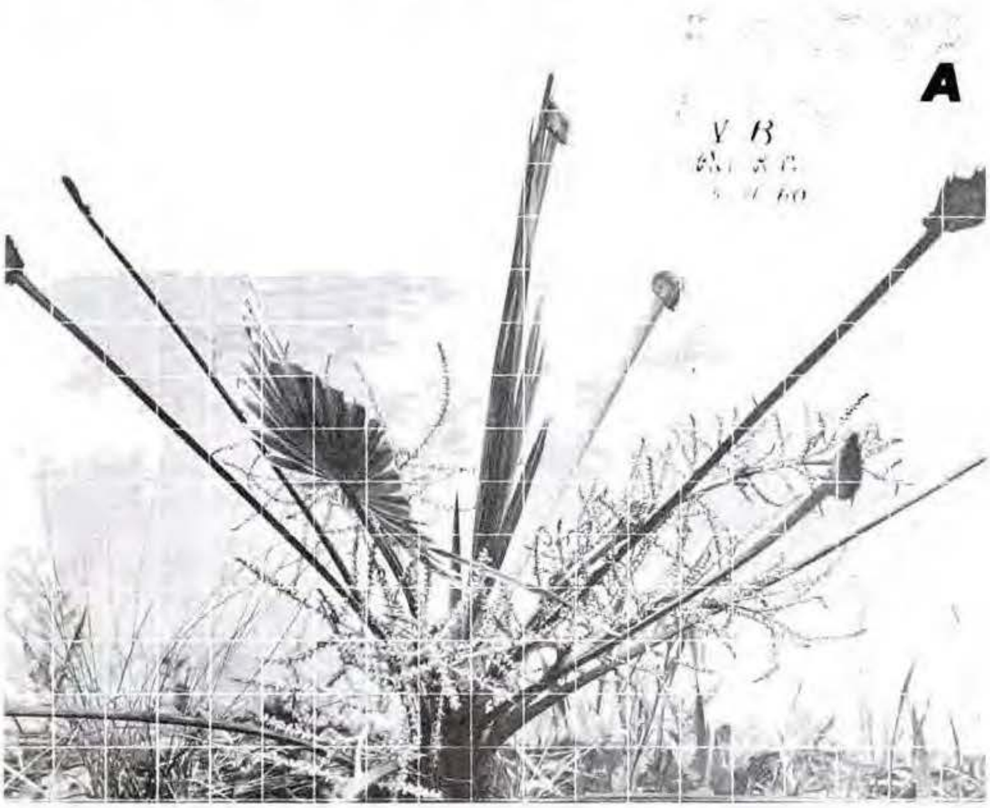


Figure 83.—Number of fires per day and acres burned per day versus numerical burning index on the 8-100-0 meter. Georgia, 1959.

The only significant gallberry moisture content fluctuations detected in 1960 were caused by new leaf growth in the spring. Peak moisture contents averaged 111 percent. The lowest content measured was in the winter — 98 percent — but there were no significant differences between the summer, fall, and winter periods. Wiregrass moisture content averaged 60 percent throughout the year with no significant fluctuations during any of the four seasons. During the study period, soil moisture at the 6-inch level ranged from a low of 11 percent to a high of 26 percent. The water table level reached a low of 45 inches and at times was at the surface of the ground.

Vegetative moisture content studies involve a number of sampling problems. In an 8-year-old slash pine plantation on a uniform site, significant within- and between-tree moisture content variation was detected. The moisture content of new growth was found to be invariably higher than in more mature growth — 60 percent higher in the case of twigs and 30 percent higher in the case of needles. The effect of crown position (upper, middle, or lower) on vegetative moisture content was significant for twig samples only. Using the data from six stripped trees (fig. 87), the variation between trees proved to be significant in spite of comparable stem and branch form. No significance was evident because of north or south exposure.



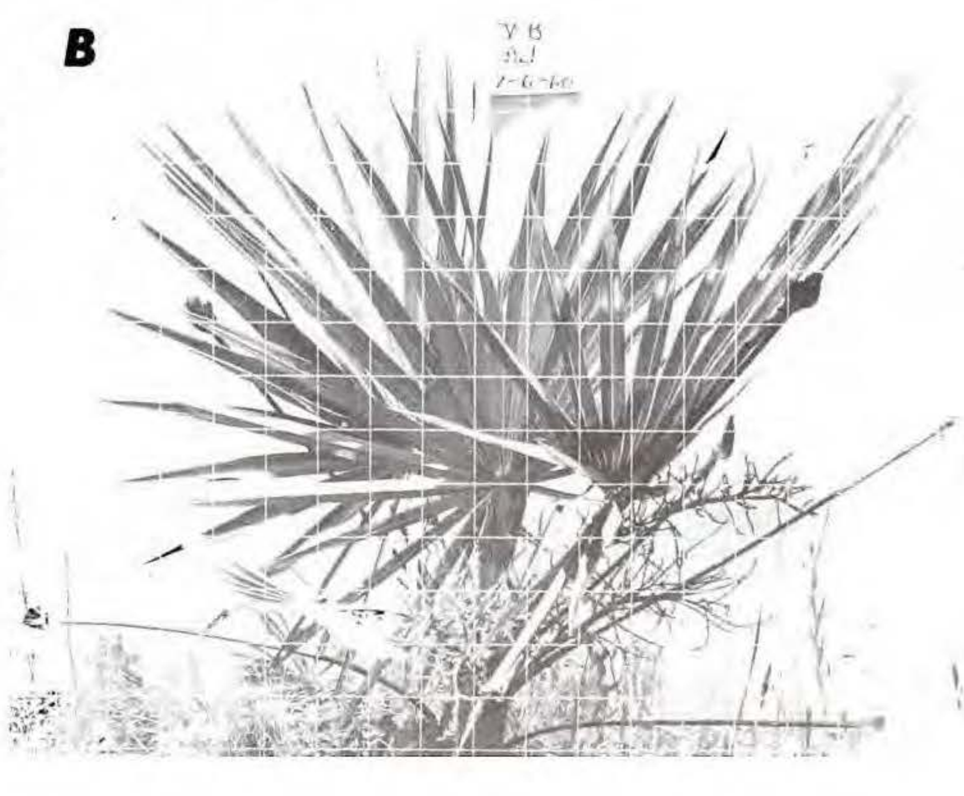


Figure 85.—Photo-grid techniques are being investigated as a means of measuring vegetative fuel weights. (A), Palmetto plant 2 months after a single winter backfire. (B), Same palmetto plant 2 months later, showing fast regrowth.

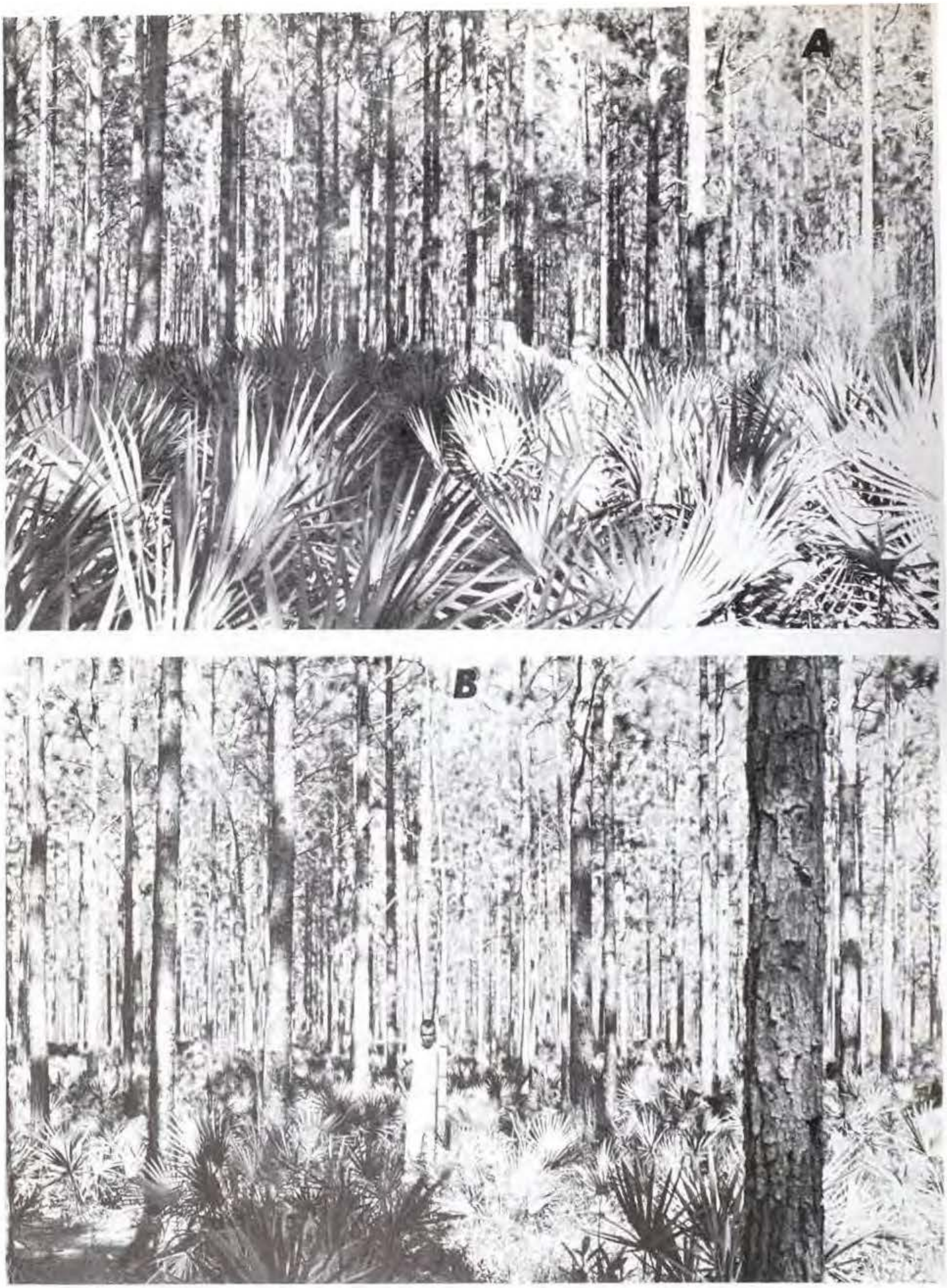


Figure 86.—*(A), Most of a palmetto plant's regrowth occurs within the first year following a single winter backfire. In an 18-month period, this fuel plot equalled its original height before burning. (B), In the 12-month period following a fall strip-head fire (preceded by a winter backfire) palmetto height regrowth was retarded approximately 30 percent and accompanied by an 8-percent mortality loss.*

Figure 87.—Within- and between-tree moisture contents are being investigated by stripping vegetation from the main stems of selected trees, separating the material into age, position, composition, and exposure classes, and calculating moisture percents from fresh and ovendry weights.

Fire Effects

A basic approach in evaluating forest fire damage to tree stems was started at the Southern Forest Fire Laboratory in 1960. Since the thermal diffusivity of bark and wood is one of the most important factors governing heat flow in a tree stem under given external conditions, precise measurements of this property must be made before heat transmission from a thermal source to the cambial layer can be properly evaluated. Thermal diffusivity is being computed from determinations of thermal conductivity, specific heat capacity, and density of the material (figures 88 and 89). Using a technique known as a transient line heat source — also called the heated probe method — thermal conductivity values ranging from 156×10^{-6} to $290 \times 10^{-6} \frac{\text{cal.}}{\text{cm}^2 \text{sec.} \frac{(^{\circ}\text{c})}{\text{cm}}}$ have been obtained for ovendried bark samples with densities of 0.38 to 0.70 gm./cm^3, respectively.

Since bark and wood moisture contents and ambient temperatures also affect thermal values, conductivity and specific heat values are being measured for a wide range of moisture and temperature conditions. Moisture contents in the outer bark of tree stems were found to vary both vertically and laterally; they were higher at the ground level than they were up the stem and increased gradually from the outer surface to the last formed periderm. Moisture measurements in this portion of the bark ranged from a low of 11 percent to a high of almost 100 percent of ovendry weight. Phloem (inner bark) moisture contents for the four major southern pines were found to range from 144 to 300 percent, whereas those for sweetgum and green ash averaged between 60 and 135 percent of dry weight.

Figure 88.—The heart of the thermal conductivity apparatus is a small probe 4 inches long and 0.020 inch in diameter that contains a heating coil. After the probe is mounted in a bark specimen, a known quantity of heat is generated by the coil and the temperature rise of the probe is indicated by means of a thermocouple. The equipment is housed in a constant temperature box for temperature control, and a desiccator jar and saturated salt solutions are used to control humidity.

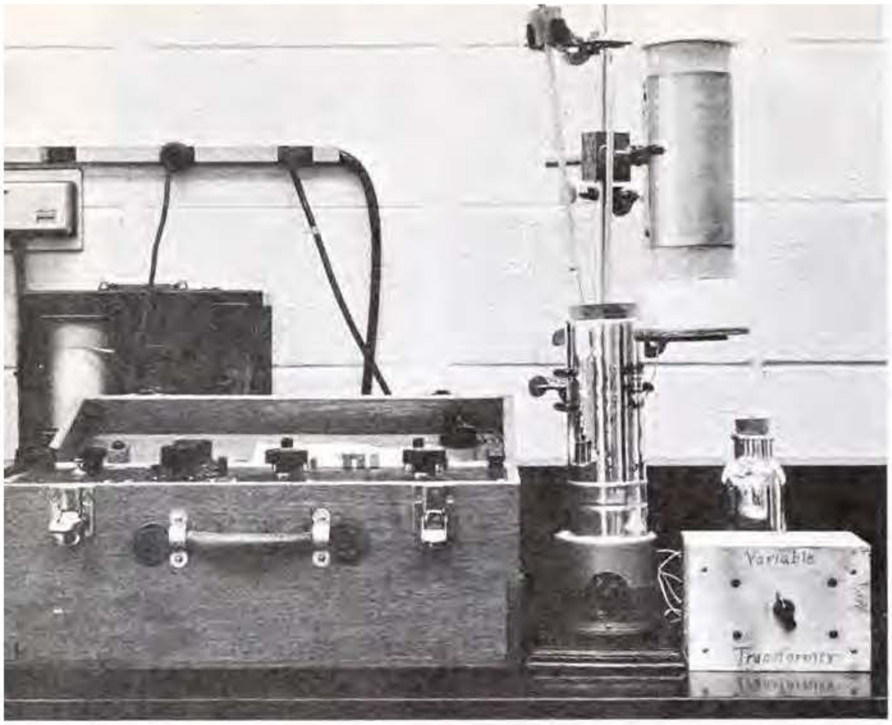


Figure 89.—Specific heat of bark is being measured by an approved ASTM test method. Specimens are mounted in a watertight brass capsule and heated electrically to a constant temperature in an open-end, radiation-type heater (upper right corner of photo). When the specimen temperature is constant, the capsule is lowered into a vacuum flask containing a known volume of water and the temperature change of the water is recorded. This information along with the temperature change of the capsule and the heat capacity of the system permits the calculation of specific heat.

Fire Retardants

During the summer of 1960, penetration and resulting ground patterns of aerially released fire retardants through a well-stocked hardwood stand in full leaf were measured. Retardant solution loads of 440 gallons, delivered by a TBM aerial tanker flying 75 to 100 feet above the 100-foot tall hardwoods, failed to penetrate the canopy in appreciable quantities except where natural openings occurred. Although the ground patterns averaged 400 feet in length and 100 feet in width, application rates averaged less than 0.1 gallon per 100 square feet of surface area. Repeat trials are being made in the same stands when the trees are bare of foliage.

In order to evaluate the residual effect of retardant solutions on plant survival and growth, a clearcut area that had been subjected to aerial drops of sodium calcium borate and monoammonium phosphate was disked and planted with slash pine. One-year remeasurements show no differences in survival, but first year height growth in the phosphate plots averaged 40 percent more than in the borate or check plots.

Increasing the viscosity of fire retardant solutions has shown promise of improving the extinguishing or retarding action. Results from treated fuel beds burned in the laboratory combustion room (fig. 90) and natural palmetto-gallberry fuel types treated in the field, however, indicate that the nature of the fuel involved and the means of retardant application may dictate the degree of viscosity desirable. For example, unthickened fire retardants will stop a surface fire running through heavy litter more effectively than a thickened mixture, particularly when applied at low rates under low pressures. The greater interception of the highly viscous retardant by the surface layer of the litter reduces penetration into the

Figure 90.—The effect of viscosity additives in retardant solutions is evaluated by measurements of rate of fire spread, penetration, fuel consumption, and temperature for treated fuel beds.

Figure 91.—A retardant mixture is sprayed on a naval stores face prior to prescribed burning.

lower levels. On the other hand, when a fire is burning primarily in aerial fuels, such as shrubs or tree crowns, a thickened mixture would probably be favored. Work in the refinement of ammonium phosphate mixtures is continuing.

The use of fire retardant materials as a protection for naval stores faces in an area that is to be prescribe burned during a long turpentining period was explored during 1960. Applications to the face itself have been unsuccessful (fig. 91). Although heavy sprays on the litter and vegetative fuel in front of the face have provided adequate protection, the treatment is costlier than mechanical means.

Fuels and the Blowup Potential

The problem of describing fire behavior in numerical terms requires the description in similar terms of the contribution of the numerous variables which influence fire behavior. One example is the contribution of the atmospheric variables. Their role in fire behavior has been given considerable attention in recent years. Another group of variables concerns forest fuel — the basic energy source of all forest fires.

One of the main objectives of a fuel classification or rating system is to describe fuels in terms which will afford a quantitative estimate of their fire behavior potential. A logical starting point, both from the standpoints of simplicity and fire behavior significance, is the development of fuel parameters which are a measure of the dominating characteristics of the behavior of a high-intensity fire burning under conditions such that all of the fuel burns (that is, when the available fuel is equal to the total fuel). If spotting is taken as the dominating characteristic, then the ember-lifting capacity of a fire's convection column becomes a key factor. Using energy relationships, it is then possible to develop the simplified scaling law

$$W/W_0=(w/w_0)^2$$

in which W is the weight of an ember that can be supported in the convection column over a fire burning in a fuel for which the weight per unit ground area is w. The quantity W_0 is the corresponding ember weight for a fire burning in a fuel with a reference weight w_0 per unit of ground area. To express the scaling equation in this simple form, it is necessary to hold other variables, such as rate of spread, heat yield, and ember density constant, but this does not affect the general validity of the relationship.

The quantity $(w/w_0)^2$ is the desired parameter and may be designated as the blowup potential. The quantity w_0 is arbitrary and can be given any convenient value. A suitable value may be chosen as 6 tons per acre because the high-

intensity fires have occurred in heavier fuels. There are physical as well as statistical reasons for this choice but a discussion of this point will not be given here. The possible use of the blowup potential in rating fuels is shown in table 11. The blowup potential is given both in numerical form and in a descriptive form of seven classes ranging from very low to very high.

To designate $(w/w_0)^2$ as the blowup potential, the fuel weight w per unit ground area should be the total fuel weight (ovendry basis) or the weight of the fuel which burns under very dry conditions. However, it is not necessary to restrict the use of the quantity $(w/w_0)^2$ to these conditions. In the lower-intensity fires only a part of the fuel burns, so if w is designated as the available fuel it would be possible to extend the application of the parameter to fires burning under any conditions. In order to do this it would be necessary to relate the available fuel to fuel moisture, fuel size, and fuel arrangement. There are two very promising additional parameters for doing this. One is the timelag concept which can be applied to the relative drying rates of the different fuel components. The other is the combustion rate which may be defined as the rate of energy release per unit of ground area when fuels are lighted simultaneously over an extended area.

If, for a given moisture condition, a fuel type's fire behavior potential could be characterized in terms of three relatively simple parameters (the quantity $(w/w_0)^2$, a timelag function, and the basic combustion rate), then this would be a substantial step forward in the rating and classification of fuel in numerical fire behavior terms.

The Timelag Concept in the Drying of Fuels

At a given temperature and relative humidity the loss of moisture from woody substances can be expressed to a close approximation by an exponential curve. The existence of such a relationship affords a simple method for expressing the drying rate of a fuel sample in terms of a single quantity which may be defined as the timelag. Physically this is the time required for the fuel sample in an atmosphere of constant temperature and humidity to lose about 63 percent of the moisture it would lose if left in such an atmosphere for an infinite time. Figure 92 shows how the actual moisture content of a ¼-inch square basswood rod decreases with time in an atmosphere with a temperature of 70° F. and a relative humidity of 40 percent.

Table 11.—Blowup of potential for different weight classes of the pocosin fuels of eastern North Carolina

Total fuel weight classes (Tons per acre)	Fuel type			Blowup potential	
	Symbol 1/	Name	Total weight	2/ $(w/w_0)^2$	Description
			Tons per acre		
2.9- 4.0	--	--	--	--	Very low
4.1- 5.7	(G-5	Wire grass	4.5	0.55	Low
	(P-5	Low pocosin--open	5.7	.90	
5.8- 8.0	(GB-7	Grass--low brush	6.4	1.14	Medium low
	(RG-7	Low reeds--grass	6.5	1.17	
	(P-10	Low pocosin--dense	8.4	1.99	
	(B(SR)-10	Low brush (sand ridge)	8.6	2.02	
8.1-11.0	(RB-10	Medium reeds--brush	8.8	2.13	Medium
	(BG(SR)-10	Low brush--grass (sand ridge)	8.8	2.16	
	(BG-10	Medium brush--grass	9.4	2.43	
	(R-10	High reeds	10.1	2.82	
11.1-16.0	(R-14	Very high reeds	13.2	4.84	Medium high
	(P-14	High pocosin	15.0	6.25	
16.1-23.0	(B-20	High brush	17.3	8.35	High
	(B(S)-20	High brush (swamp)	21.0	12.2	
23.1-32.0	--	--	--	--	Very high

1/ G = wire grass; P = pocosin; B = brush; R = reeds (cane); (S) = swamp; SR = sand ridge; 5, 7, etc. are midpoints of the total fuel weight classes in tons per acre.

2/ Reference weight, w_o, is 6.0 tons per acre.

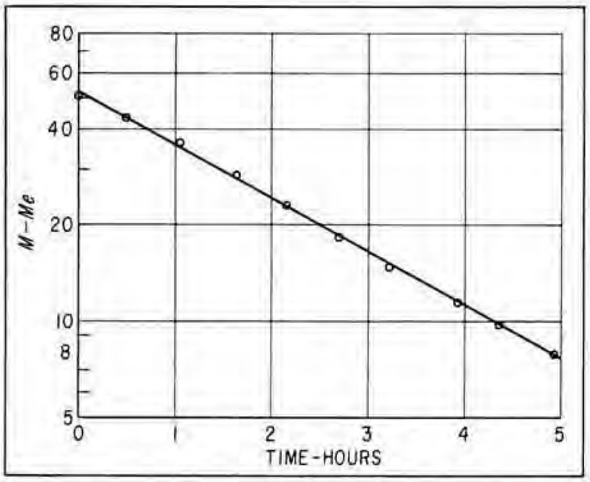


Figure 92.—The difference between the measured moisture content M and the equilibrium moisture content M_e is plotted as a function of the time of drying.

The exponential relationship is indicated by the straight line semilog plot. Values of the ordinate represent differences between the measured moisture content M and the equilibrium moisture content M_e. In this example the timelag is about 2.6 hours. Ordinarily it is desirable to reduce such drying curves to a reference, or standard, temperature-humidity combination, in which case the timelag may be designated as the timelag constant for that particular fuel. If this standard is chosen as an 80° F. temperature and a 20 percent relative humidity, the timelag constant for the basswood rod used as the test sample in figure 92 is about 1.5 hours.

At the Southern Forest Fire Laboratory drying curves similar to that in figure 92 have been obtained for square sticks ranging from 1/16 inch to 4 inches in diameter and for sawdust layers ranging from ¼ inch to 4 inches thick (fig. 93). Data for samples of other shapes have also been obtained. With the exception of the highest moisture contents, at which the samples tend to lose moisture like a free water surface, the exponential law seems to give a close approximation of the drying process.

Possibly the two most immediate uses of the timelag concept would be in the design of fire danger rating systems and in the rating or classification of forest fuels in terms of their fire behavior potential. For fuel studies it is desirable to express the timelag in a dimensionless form which makes it independent of factors such as temperature, relative humidity, or wind movement. In its dimensionless form the timelag becomes a timelag number in terms of which it may be possible to describe the drying of a complex heterogeneous fuel by means of a single curve which would be a function only of the fuel characteristics (primarily the size and arrangement of the fuel components). Owing to the close similarity of the heat and moisture transfer processes, this same curve may also be closely related to the combustion characteristics of the heterogeneous fuel. However, more work will be required on this phase of the problem.

Figure 93.—Research Forester John Keetch inspects the timelag constant study in the outdoor laboratory area. Birch and basswood samples from 1/16 to 4 inches in diameter as well as pine sawdust, are being exposed to determine the timelags for these materials. These values will be correlated with actual forest fuels.

PUBLICATIONS

by

MEMBERS OF THE STAFF, INCLUDING COOPERATORS

Calendar Year 1960

ADAMS, H. E., and SCHOCH, M. S.
1959 forest fires and fire danger in Connecticut, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia.
(Thirteen separate reports containing tables and graphs analyzing forest fires and fire danger.)

ALLEN, P. H.
Scorch and mortality after a summer burn in loblolly pine. Southeast. Forest Expt. Sta. Res. Notes 144.
(Converging lines of fire resulted in severe crown scorch; mortality was largely confined to trees less than 8 inches in d.b.h.)

ANDERSON, W. C.
The small forest landowner and his woodland. Southeast. Forest Expt. Sta. Paper 114, 15 pp., illus.
(Describes the individual landowners, how they use their forest land, and their attitudes toward forestry.)

AVERY, GENE
A checklist for airphoto inspections. Photogram. Engin. 26(1): 81-84, illus.
(Systematic technical inspections of contract aerial photography: photo scale, print overlap, evaluations on each flight line.)

AVERY, GENE
Identifying southern forest types on aerial photographs. Southeast. Forest Expt. Sta. Paper 112, 12 pp., illus.
(Main differences between panchromatic and infrared photographs from the standpoint of timber type mapping.)

BARNES, R. L., and NAYLOR, A. W.
Studies on the ornithine cycle in roots and callus tissues of *Pinus serotina* and *Pinus clausa*. Bot. Gaz. 121(2): 63-69.
(Pond pine was more active than sand pine in metabolizing ornithine-2-C^{14}, $NaHC^{14}O$, and sodium formate-C^{14} via citralline and arginine.)

BENNETT, F. A.
Height growth pattern and thinning of slash pine (*Pinus elliottii* var. *elliottii*). Jour. Forestry 58: 561-562, illus.
(Relation of increasing crown area to thinning response. Emphasizes role of height growth in crown area increase.)

BENNETT, F. A.
Spacing and early growth of planted slash pine. Jour. Forestry 58: 966-967.
(Competition developed during fifth year at a density of 500-550 trees per acre; the effect of stand density intensified in the sixth and seventh years.)

BETHUNE, J. E.
Distribution of slash pine as related to certain climatic factors. Forest Sci. 6: 11-17, illus.
(Discriminant function analysis of relation of monthly averages of temperature and precipitation by seasons and average length of frost-free period to areas within range of natural distribution and areas outside of, but adjacent to, slash pine range.)

BETHUNE, J. E., and LEGRANDE, W. P.
Profitable small-forest management—a case history. Forest Farmer 20(1): 12-13, 38, illus.
(Reports 10 years of farm woodlot operations on the Santee Experimental Forest.)

BETHUNE, J. E., and ROTH, E. R.
Fifth year results of loblolly pine seed source planting in Georgia. Southeast. Forest Expt. Sta. Res. Notes 145.
(Seedlings of northern sources grew slower than those of southern origin. Infection by southern fusiform rust was related to seed origin but not temperature zone.)

BETHUNE, J. E., and ROTH, E. R.
Source of seed affects growth of longleaf pine — fifth year results. Southeast. Forest Expt. Sta. Res. Notes 146.
(Discusses seedling height, seedling survival and branch length, time in grass stage, percent of trees forked, and percent infected by brownspot needle blight.)

BINGHAM, R. T., SQUILLACE, A. E., and WRIGHT, J. W.
Breeding blister rust resistant western white pine. Silvae Genetica 9, Heft 2: 33-41.
(Narrow-sense heritability was 68 percent and broad-sense heritability 87 percent for rust resistance as estimated by the method of expectation mean squares for four different groupings of related progenies.)

BOYCE, J. S., Jr.
An appraisal of Fomes annosus in Scotland. Forest Farmer 20(3): 10, 17.
(Observations on stump treatments to reduce initial stand infection and incidence of butt and root rot in various conifers planted in one area.)

BOYCE, J. S., Jr.
Distribution of Ceratocystis fagacearum in roots of wilt-infected oaks in North Carolina. Phytopathology 50(10): 775-776.
(Only one root-graft infection court was found by excavating and culturing 46 infected roots of 23 wilting oaks.)

BOYCE, J. S., Jr.
Rot and rust. Young trees face grim future unless research can find successful control. Amer. Tree Farmer & Forestry Digest, p. 8. July.
(Describes fusiform rust and *Fomes annosus* and the rerearch needed to develop better control methods for them.)

BOYCE, J. S., Jr., and SPEERS, C. F.
Oak dieback in Virginia in 1959. Plant Dis. Rptr. 44(5): 351.
(The oak pit-making scale *Asterolecanium* sp. and the fungus *Dothiorella quercina* were closely associated with extensive dieback of chestnut and white oaks in western Virginia.)

BRENDER, E. V.
Growth predictions for natural stands of loblolly pine in the lower Piedmont. Ga. Forest Res. Council Rpt. 6, 7 pp., illus.
(Analyses of 5- to 12-year growth in relation to age, site, and stand density on 202 stands comprising 1,552 acres on the Hitchiti Experimental Forest.)

BRENDER, E. V.
Progress report on control of honeysuckle and kudzu. Thirteenth Ann. South. Weed Conf. Proc. 1960: 187-193.
(Behavior and control of honeysuckle and kudzu.)

BRENDER, E. V., and ROMANCIER, R. M.
Glaze damage in loblolly pine plantations. South. Lumberman 201(2513): 168, illus.
(Loblolly pine plantations in areas subject to glaze should be thinned lightly and frequently from below, or cut selectively.)

BROWN, H. J.
Publications of the Southeastern Forest Experiment Station, 1921-1958. Southeast. Forest Expt. Sta. Paper 117, 115 pp.
(An alphabetical author list of 1700 research reports by members of Station staff and cooperators from 1921 through 1958.)

BRYAN, W. C.
Losses from defect in Piedmont hardwoods. Southeast. Forest Expt. Sta. Paper 109, 31 pp., illus.
(Epicormic and adventitious branching and small knots are the most prevalent defects, probably because of small average size of trees.)

CAMPBELL, R. A.
Does site affect grade yield? Soc. Amer. Foresters Proc. 1959: 50-53, illus.
(Although log grade is the most important single variable, site also affects lumber yields and values of both logs and trees.)

CLEMENTS, R. W.
Manual, modern gum naval stores methods. Southeast. Forest Expt. Sta., 29 pp., illus.
(The most efficient gum extraction methods are illustrated by photographs and drawings.)

CLUTTER, J. L.
Appropriate sampling designs for continuous forest inventory systems. Short Course in Continuous Inventory Control in Forest Mangt. Proc. Univ. Ga. School Forestry 1959: 162-168.
(Advantages and disadvantages of sampling schemes adaptable to CFI systems.)

CLUTTER, J. L.
The use of medium-sized electronic computers in the processing of continuous forest inventory data. Short Course in Continuous Inventory Control in Forest Mangt. Proc. Univ. Ga. School Forestry 1959: 63-68.
(Procedures and advantages of medium-sized electronic computers for CFI data processing, using IBM 650 as example.)

DAVIS, L. S., and MARTIN, R. E.
Time-temperature relationships of test head fires and backfires. Southeast. Forest Expt. Sta. Res. Notes 148.
(In gallberry-palmetto roughs, head fire and backfire temperatures reached a maximum of 1600° F., and 600° F., respectively. Temperatures at the 1-foot level were higher than those at the 4-foot level.

DAVIS, ROBERT
Parasites of the elm spanworm, Ennomos subsignarius (Hbn.) in Georgia. Ent. Soc. Wash. Proc. 62(4): 247-248.
(Results of parasite recovery from elm spanworm pupae and larvae.)

DOOLITTLE, W. T., and VIMMERSTEDT, J. P.
Site index curves for natural stands of white pine in the southern Appalachians. Southeast. Forest Expt. Sta. Res. Notes 141.
(Curves based upon 105 plots of white pine ranging from 22 to 78 years of age and tree heights from 36 to 114 feet.)

DOUGLASS, J. E.
Soil moisture distribution between trees in a thinned loblolly pine plantation. Jour. Forestry 58: 221-222, illus.
(Shows that variation in soil moisture is related to tree location, and discusses associated sampling problems in plantations.)

DROOZ, A. T.
The elm spanworm outbreak in the southern Appalachians. South. Lumberman 201(2513): 111, illus.
(Unusual aspects of the 6-year-old outbreak in Georgia, North Carolina, and Tennessee.)

EBEL, B. H., MERKEL, E. P., and KOWAL, R. J.
Key to southern forest insects — based on damage symptoms. Forest Farmer Manual 19(7): 106-107, illus.
(Identification of destructive forest insects by their damage symptoms.)

FAHNESTOCK, G. R., and JOHANSEN, R. W.
Will borate kill southern timber? Fire Control Notes 21(3): 87-93.
(Effects of sodium calcium borate slurries on southern species.)

GOEBEL, N. B., TARAS, M. A., and SMITH, W. R.
Tension wood and its relation to splitting in hickory. S. C. Agr. Expt. Sta. Bul. 480, 21 pp., illus.
(A study of internal stresses that cause end splitting in hickory logs.)

HAASIS, F. A., and HODGES, C. S.
An angular leaf spot of Magnolia grandiflora caused by Isariopsis sp. (Abs.) Phytopathology 50(9): 637.
(Controlled inoculations confirmed that *Isariopsis* sp. caused a previously undescribed leaf spot of 1- and 2-year-old seedlings in North Carolina.)

HALLS, L. K., HUGHES, R. H., and PEEVY, F. A.
Grazed firebreaks in southern forests. U. S. Dept. Agr Info. Bul. 226, 8 pp., illus.
(Location and selection, clearing and land preparation, what to plant, fertilization and liming, seeding and grazing.)

HANEY, G. P.
Forest research in Virginia by the U. S. Forest Service. Va. Tech. Forester 12: 29-32.
(Reports Southeastern Forest Experiment Station research program in Virginia.)

HEPTING, G. H.
Differentiating needle blights of white pine in the interpretation of fume damage. (Abs.) Third Air Pollut. Res. Seminar Syllabus 1960: 31.
(Symptoms for several disease entities that produce needle blights of white pine.)

HEPTING, G. H.
The problem of forest diseases — and how to meet it. Forest Farmer Manual 19(7): 108-110.
(Economically important tree diseases in the South and measures for combating them.)

HEPTING, G. H.
Spot anthracnose and other diseases of dogwood. Arborist's News 25(4): 25-28, illus. Also, with title Spray program for dogwood diseases, Amer. Nurseryman 112(9): 112-114.
(A suggested spray program for controlling spot anthracnose, Ascochyta blight, Septoria leafspot, and Botrytis blight, each of which is briefly described.)

HEPTING, G. H.
The threat of pathogens. Fourth Conf. on South. Indus. Forest Mangt. Proc., Duke Univ. School Forestry, pp. 22-27.
(Pure stands of trees are particularly vulnerable to disease. Describes six serious threats to monocultures.)

HEWLETT, J. D., and METZ, L. J.
Watershed management research in the Southeast. Jour. Forestry 58: 269-271, illus.
(Reviews watershed management research of the Southeastern Forest Experiment Station at the Coweeta Hydrologic Laboratory and Union Research Center.)

HODGES, C. S.
Effect of soil fumigation in the nursery on growth of loblolly pine seedlings and control of weeds. Tree Planters' Notes 42: 23-27.
(Describes tests using different formulations and applications of methyl bromide, Vapam, Brozone, Eptam, and Nemagon.)

HODGES, C. S., and GREEN, H. J.
Survival in the plantation of eastern redcedar seedlings infected with Phomopsis juniperovora in the nursery. (Abs.) Phytopathology 50(9): 639.
(Results show that infected seedlings should be culled from planting stock.)

HOEKSTRA, P. E.
Counting cones on standing slash pine. Southeast. Forest Expt. Sta. Res. Notes 151.
(Method for estimating number of cones on standing trees.)

HOEKSTRA, P. E.
Problems of slash pine seed supply. Soc. Amer. Foresters Proc. 1959: 24-25.
(Methods of increasing slash pine cone crops through cultural means and cone protection.)

HOPPER, B. E., and PADGETT, W. H.
Relationship of nemas (nematodes) with the root rot of pine seedlings at the E. A. Hauss State Forest Nursery, Atmore, Alabama. Plant Dis. Rptr. 44(4): 258-259.
(Soil samplings showed that nematodes probably did not cause the root rot.)

HUGHES, R. H., DILLARD, E. U., and HILMON, J. B.
Vegetation and cattle response under two systems of grazing cane range in North Carolina. N. C. Agr. Expt. Sta. Bul. 412, 27 pp., illus.
(Alternate yearlong and summer-winter systems of grazing cane range gave about equal cattle performance, but continuous summer grazing hastened decadence of cane stands.)

HUPPUCH, C. D.
The effect of site preparation on survival and growth of sycamore cuttings. Southeast. Forest Expt. Sta. Res. Notes 140.
(Discing plus cultivation was best for maximum height growth but the less expensive double furrowing gave better survival and satisfactory height growth.)

HUPPUCH, C. D.
Observations on white oak stem swellings. Plant Dis. Rptr. 44(4): 238-239, illus.
(Unusual swellings have been noted on white oaks in the mountains of north Georgia and western North Carolina; no causal agent has been found.)

JANSSEN, P. L., and WEILAND, M. R.
Softwood distribution maps for the South. South. Forest Expt. Sta. Forest Survey Release 83, 12 pp., illus.
(Range and growing stock volume of 11 principal softwood species.)

JOHNSON, E. A., and MEGINNIS, H. G.
Effect of altering forest vegetation on low flow of streams. Comm. Surface Waters, Gen. Assembly of Helsinki, Inter. Assoc. Sci. Hydrol. Pub. 51:257-266, Gentrugge, Belgium.
(Controlled watershed experiments show large increases in low flows after cutting mountain hardwood stands in North Carolina; and appreciable decreases in flow after pines were planted on a small Ohio watershed.)

JONES, LEROY
Rapid moisture determination of tree seed with an electronic meter. Tree Planters' Notes 43: 7.
(Describes electronic moisture meter which satisfactorily determines moisture content of tree seed.)

KELMAN, ARTHUR, HODGES, C. S., and GARRISS, H. R.
Needle blight of redcedar, Juniperus virginiana L. Plant Dis. Rptr. 44(7): 527-531.
(Symptoms and control of needle blight of redcedar, with a description of the causal fungus, *Exosporium glomerulosum*.)

KOWAL, R. J.
Insects commonly attacking forest trees and products in the South. Forest Farmer Manual 19(7): 101-105, illus.
(Description, recognition, and control of most destructive forest tree and products insects.)

KOWAL, R. J.
The problem of tree killing insects — and how to meet it. Forest Farmer Manual 19(7): 98-100.
(Detection and reporting of insect outbreaks. Research on control of important southern forest pests.)

KOWAL, R. J.
Southern pine beetle. U. S. Dept. Agr. Forest Pest Leaflet 49, 7 pp., illus.
(Distribution, hosts, evidence of attack, description of stages, life history, habits, and control.)

KRAUS, J. F.
Tree improvement research at Lake City, Florida. Alumni News, N. Y. State Ranger School 1959: 22-27.
(Summary of tree improvement work now under way at Lake City Research Center.)

KRAUS, J. F., and BENGTSON, G. W.
The use of irrigation in forestry. *In* Forest soils. Eighth Ann. Forestry Symposium Proc., La. State Univ. School Forestry 1959: 96-105.
(Research problems and problems in practical application of forest irrigation.)

KRAUS, J. F., and JOHANSEN, R. W.
A test of gibberellic acid on longleaf pine. Jour. Forestry 58: 194.
(Negative results with treatment of longleaf seedlings with various concentrations of gibberellic acid.)

LARSON, R. W.
South Carolina's timber. Southeast. Forest Expt. Sta. Forest Survey Release 55, 103 pp., illus.
(Illustrated presentation of current timber supply trends, possible future needs, and problems that must be solved to increase timber supply.)

LOTTI, THOMAS
Silvical characteristics of shumard oak. Southeast. Forest Expt. Sta. Paper 113, 10 pp., illus.
(Extent and climate of botanical range, edaphic and physiographic site conditions, reproductive and growth habits, ecology, plant and animal pests, and response to management.)

LOTTI, THOMAS
Silvical characteristics of swamp chestnut oak. Southeast. Forest Expt. Sta. Paper 110, 8 pp., illus.
(Extent and climate of botanical range, edaphic and physiographic site conditions, reproductive and growth habits, ecology, plant and animal pests, and response to management.)

LOTTI, THOMAS
The use of fire in the management of coastal plain loblolly pine. Soc. Amer. Foresters Proc. 1959: 18-20, illus.
(Results and conclusions of prescribed burning studies dating back to 1946 on Santee Experimental Forest.)

LOTTI, THOMAS, KLAWITTER, R. A., and LEGRANDE, W. P.
Prescribed burning for understory control in loblolly pine stands of the coastal plain. Southeast. Forest Expt. Sta. Paper 116, 19 pp., illus.
(Over 10 years' study in use of prescribed burning on the Santee and Westvaco Experimental Forests in South Carolina.)

MALOY, O. C., and MATTHEWS, F. R.
Southern cone rust: distribution and control. Plant Dis. Rptr. 44(1): 36-39, illus.
(Cone rust, most prevalent on slash pine in northern Florida, was experimentally reduced by carefully timed sprays of ferbam.)

MATTHEWS, F. R., and MALOY, O. C.
What to do about cone rust. Forest Farmer 19(4): 8, 14-15.
(Cone rust distribution, damage, symptoms, and control.)

MEGINNIS, H. G.
Watershed management research — challenging career for young scientists. Ames Forester 47: 20-23, illus.
(Reviews knowledge, outlines research needs and opportunities for specialists from many disciplines.)

METZ, L. J.
An American forester visits the Soviet Union. Forest Farmer 19(5): 10-11, 21.
(Author was member of 7-man forestry exchange team which visited the USSR during 1959.)

METZ, L. J.
The de la Howe old-growth forest in Piedmont shortleaf pine. Jour. Forestry 58: 807-809, illus.
(Describes history and condition, emphasizes the value of such bench marks for study of natural potential, soil-plant relations, and forest disease impacts.)

METZ, L. J.
Hydrologic properties of southern forest soils. *In* Forest soils. Eighth Ann. Forestry Symposium Proc., La. State Univ. School Forestry 1959: 19-24.
(Properties of soil profile affecting movement and storage of water and importance of maintaining favorable hydrologic properties.)

NELSON, T. C.
Relationship of growth to growing stock. pt. 2. Current research in the South. Fourth Conf. South. Indus. Forest Mangt. Proc. Duke Univ. School Forestry 1960: 52-62.
(Summarizes growth and yield studies currently under way in the southern states.)

NELSON, T. C.
Silvical characteristics of bitternut hickory. Southeast. Forest Expt. Sta. Paper 111, 9 pp., illus.
(Extent and climate of botanical range, edaphic and physiographic site conditions, reproductive and growth habits, ecology, plant and animal pests, and response to management.)

PECHANEC, J. F.
How mills can help improve the forest survey. APA Tech. Paper 60-P12, 5 pp.
(States and industries help speed up and strengthen forest surveys. Other cooperative steps are suggested.)

PETER, RALPH
Firing charcoal kilns with the doors open. Southeast. Forest Expt. Sta. Res. Notes 142.
(Open-door firing results in more nearly uniform ignition and can reduce coaling time as much as 24 hours.)

REINES, M., and McALPINE, R. G.
The morphology of normal, callused, and rooted dwarf shoots of slash pine. Bot. Gaz. 121(2): 118-124, illus.
(Individual needles are capable of callus formation and root development. Cortex and pitch contribute largely to callus formation but cambial cells and parenchyma also capable of proliferation.)

RIPLEY, T. H.
Weights of Massachusetts quail and comparisons with other geographic samples for taxonomic significance. AUK 77: 445-447.
(Reports live weights by age and sex for a series of wild-trapped Massachusetts quail; and discusses possible validity of subspecific recognition.)

RIPLEY, T. H., and CAMPBELL, R. A.
Browsing and stand regeneration in clear- and selectively-cut hardwoods. Twenty-Fifth No. Amer. Wildlife Conf. Trans. 1960: 407-415.
(Reports regeneration benefits from heavy cutting and considers problems in relation to deer browsing of reproduction.)

RIPLEY, T. H., JOHNSON, F. M., and THOMAS, W. P.
A useful device for sampling understory woody vegetation. Jour. Range Mangt. 13: 262-263, illus.
(Describes a rod with leveling device for establishing vertical lines or planes of reference, and discusses various uses in understory sampling.)

RODENBACH, R. C.
Sources of lumber for furniture plants in North Carolina. Furniture, Plywood and Veneer Council of the N. C. Forestry Assoc., Inc., 5 pp., illus.
(Breakdown by states and species for 354 million feet purchased in U. S. in 1958. Foreign sources by species only.)

RODENBACH, R. C., and DOYLE, H. J.
Thickness variation of lumber cut in 1959 by circular mills in North Carolina. Furniture, Plywood and Veneer Council of the N. C. Forestry Assoc., Inc., 9 pp., illus.
(One-third of all lumber received at N. C. furniture plants in 1959 was too thick to meet specifications, too thin, or otherwise miscut.)

RODENBACH, R. C., and OLSON, D. F., JR.
Grading yellow-poplar planting stock is important. Southeast. Forest Expt. Sta. Res. Notes 147.
(For most yellow-poplar plantings the minimum root collar diameter should be at least 0.25 inch to insure good stocking.)

ROMANCIER, R. M.
Reduction of fuel accumulations with fire. Southeast. Forest Expt. Sta. Res. Notes 143.
(Effects of repeated prescribed burns on depth and character of forest floor in Tidewater Virginia.)

ROTH, E. R.
Plots demonstrate 16 years' loss from littleleaf. Jour. Forestry 58: 322-323.
(Almost all of 27 widely distributed plots showed heavy littleleaf losses in 16 years.)

ROW, CLARK
Soil-site relations of old-field slash pine plantations in Carolina Sandhills. Jour. Forestry 58: 704-707, illus.
(The site index of slash pine plantations can be estimated from their age, the depth to a fine-textured soil horizon, and the thickness of the A_1 horizon.)

ROWAN, S. J.
The susceptibility of twenty-three tree species to black root rot. Plant Dis. Rptr. 44(8): 646-647.
(Twenty-two conifers and one hardwood rated for susceptibility to root rot by seedling tests in greenhouse.)

RUMMELL, R. S.
An abridged history of southern range research. Iowa State Jour. Sci. 34(4): 749-760.
(Cites progress in range management and wildlife habitat research.)

ST. GEORGE, R. A., JOHNSTON, H. R., and KOWAL, R. J.
Subterranean termites, their prevention and control in buildings. U. S. Dept. Agr. Home and Gard. Bul. 64, 30 pp., illus.
(Subterranean termites, life history, habits; structural and chemical measures to prevent termite attack; methods for controlling infestations.)

SCHOPMEYER, C. S., and MALOY, O. C.
Dry face of naval stores pines. U. S. Dept. Agr. Forest Pest Leaflet 51, 7 pp., illus.
(Symptoms, predisposing factors, prevention, and control of dry face.)

SHIPMAN, R. D.
Survival and growth of graded longleaf pine nursery stock. Jour. Forestry 58: 38-39, 42, illus.
(The best survival of longleaf pine in the Carolina-Georgia sandhills results from planting grade 1 seedlings on either sands or sandy loams regardless of planting date.)

SLUDER, E. R.
Early results from a geographic seed source study of yellow-poplar. Southeast. Forest Expt. Sta. Res. Notes 150.
(Seedlings of local source had significantly higher survival but not faster growth than others. Time of height growth initiation was correlated with length of growing season, date of last killing frost, and latitude of the source of seed.)

SMART, W. W. G., Jr., MATRONE, G., SHEPHERD, W. O., HUGHES, R. H., and KNOX, F. E.
The study of comparative consumption and digestibility of cane forage (Arundinaria sp.). N. C. Agr. Expt. Sta. Tech. Bul. 140, 8 pp.
(Digestible nutrients in cane forage as affected by season, forest canopy and burning were determined using three separate recently developed indicator methods.)

SMITH, W. R.
The impact of research on the pulp and paper industry. TAPPI 43(5): 30A, 32A, 34A, 36A.
(Research in the fields of forest management, wood procurement, processes, and special utilization of byproducts.)

SOUTHEASTERN FOREST EXPERIMENT STATION
Annual report for 1959. 85 pp., illus.
(Highlights of the Station's research results.)

SQUILLACE, A. E., and BINGHAM, R. T.
Heritability of juvenile growth rate in western white pine. (Abs.) Soc. Amer. Foresters Proc. 1959: 40.
(Techniques used to estimate heritability and estimating gain under various tree improvement approaches.)

SQUILLACE, A. E., and DORMAN, K. W.
Selective breeding of slash pine for high oleoresin yield and other characters. (Abs.) 9th Internatl. Bot. Cong. Proc. 1959: 375.
(Inherent variation has been found in oleoresin yield, oleoresin viscosity, and tracheid length. Selection within the species for these traits is feasible.)

STOREY, T. G., and MERKEL, E. P.
Mortality in a longleaf-slash pine stand following a winter wildfire. Jour. Forestry 58: 206-210, illus.
(Extent of mortality according to classes of crown and stem injury.)

SWOFFORD, T. F.
Dewinging damage to slash pine seed. Tree Planters' Notes 42: 3.
(Scarification injury during dewinging may be more harmful to seed of low germination vigor than to seed of high germination vigor.)

SWOFFORD, T. F.
The effect of air drying of cones upon seed germination. Tree Planters' Notes 43: 3-4.
(Deterioration of seed due to prolonged air drying was greatest for longleaf pine. Loblolly pine seed deterioration was intermediate between longleaf and slash pine.)

TODD, A. S., Jr., and NICHOLS, A. C.
1959 Pulpwood production in the south. Southeast. Forest Expt. Sta. Forest Survey Release 56, 23 pp., illus.
(Production of round pulpwood and pulp chips from wood residues by pine and hardwood species groups and by State; also, production of roundwood by county.)

TROUSDELL, K. B.
Forest planting practices are often ineffective. Jour. Forestry 58: 718-719.
(In plantings on forest areas, natural pine regeneration often makes the planning ineffective and unnecessary.)

VICK, C. B.
Tension wood. Coop. Pub. Ga. Forestry Comn. and U. S. Forest Serv. Southeast. Forest Expt. Sta. Forest Util. Serv. Release 22.
(How to recognize tension wood in lumber and veneer so that it can be discarded in precision or quality manufacture.)

WAHLENBERG, W. G.
Loblolly pine. Duke Univ. School Forestry, Durham, N. C. 603 pp., illus.
(Comprehensive monograph on use, ecology, regeneration, protection, growth, and management of loblolly pine, summarizing author's personal experience plus review of nearly 1,500 articles.)

WELLS, C. G., and COREY, R. B.
Elimination of interference by phosphorus and other elements in the flame photometric determination of calcium and magnesium in plant tissue. Soil Sci. Soc. Amer. Proc. 24(3): 189-191.
(A rapid, accurate flame photometric method was devised for determination of Ca and Mg in plant tissue. Results agreed well with AOAC methods.)

WENDEL, G. W.
Fuel weights of pond pine crowns. Southeast. Forest Expt. Sta. Res. Notes 149.
(Formula for estimating the weight of foliage and branchwood according to tree diameter.)

WENGER, K. F.
Research charts Florida's forestry course. Forest Farmer 19(6): 16-17, 35-36, illus.
(Reviews forest research program of all agencies in Florida.)

WILHITE, L. P., and HARRINGTON, T. A.
Site preparation research in the flatwoods. South. Lumberman 201(2513): 151-152, illus.
(Describes cooperative site preparation study in southeast Georgia and northeast Florida.)

YATES, H. O., III
The Nantucket pine moth, a literature review. Southeast. Forest Expt. Sta. Paper 115, 19 pp., illus.
(Nomenclature, distribution, hosts, biology, damage, and control.)

Addenda

The following item was omitted from the Station's 1954 Bibliography:

JOHNSON, E. A., and KOVNER, J. L.
Increasing water yield by cutting forest vegetation. Ga. Min. News Letter VII(4): 145-148, illus.
(Changes in total yield, timing, and distribution of flow as related to riparian cutting, removal of forest understory, and clear cutting on experimental watersheds at Coweeta Hydrologic Laboratory.)

The following item was omitted from the Station's 1958 Bibliography:

BOURDEAU, P. F., and SCHOPMEYER, C. S.
Oleoresin exudation pressure in slash pine: its measurement, heritability and relation to oleoresin yield. *In* The physiology of forest trees, pp. 313-319. New York.
(Oleoresin exudation pressure is shown to be a variable trait that has high heritability and influences oleoresin yield.)

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